REGULATED POWER SUPPLIES

Model 6456A
Power Supply

Instruction & Operating Manual

2

HARRISON LABORATORIES

100 LOCUST AVENUE • BERKELEY HEIGHTS, NEW JERSEY 07922 • 464-1234 • AREA CODE 201 • TWX 201-464-2117

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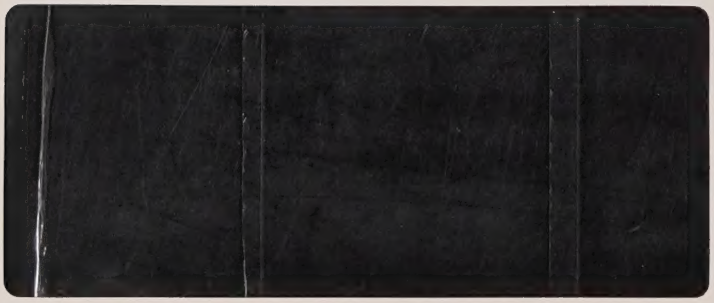

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SPECIFICATIONS

Input: 208/230/460VAC ±10%, 60 cycles, three phase*

Output: 0-32VDC, 0-100ADC.

Combined Line and Load Regulation:

Constant Voltage -- Less than 0.2% plus 10 millivolts for a full load to no load change in output current combined with a ±10% change in line voltage.

Constant Current -- Less than 1% or 1 amp whichever is greater for a full change in output voltage combined with a ±10% change in line voltage.

Ripple and Noise: Less than 1/2% RMS of maximum output voltage for any combination of line voltage, output voltage, and load current.

Transient Recovery Time: Less than 50 milliseconds is required for output voltage recovery to within 300 millivolts of the nominal output voltage following a load change from full load to half load or half load to full load.

Operating Temperature Range: 0 to 50°C.

Temperature Coefficient: Output voltage change per degree Centigrade is less than 0.05% plus 2 millivolts.

Stability: As a constant voltage source, the total drift for 8 hours (after 30 minutes warm-up) at a constant ambient is less than 0.25% plus 10 millivolts.

Overload Protection: The supply is protected for all overload conditions, including a short circuit at the output terminals. This protection is inherent in the constant voltage/constant current automatic crossover operation. The current control acts as a continuously acting limit in constant voltage operation and the voltage control acts as a voltage limit in constant current operation.

AC Line Dropout Protection: Protection is provided against an input AC line phase dropout. The supply senses the reduction of input voltage, turns off the rectifiers, and opens a power relay which isolates the output power bus. When the input returns to normal, output power is automatically reapplied to the load.

*Instructions are included for wiring for 230 or 208VAC, or unit may be ordered in original purchase contract to be wired for 460VAC.

Controls: A single control makes possible continuous adjustment of the output voltage over the entire range from 0 to 32 volts. The current control knob permits adjustment for maximum output current to the optimum value for protection of the load device. In addition, this latter control serves as the output control for constant current operation. The three phase circuit breaker serves as the ON-OFF control and as secondary protection to the instrument.

Meters: A 0-40V voltmeter and 0-100A ammeter are provided on the front panel. Internal meter calibration potentiometers are provided.

Terminals: Output power connections are made on two tapped rectangular bus bars located at the rear of the supply. Both power supply output terminals are isolated from the chassis and either the positive or negative terminal may be connected to chassis ground. The upper bus bar is positive.

Error Sensing: Remote error sensing can be accomplished from the rear programming strip.

Remote Programming: Remote programming terminals make possible external control of the output voltage or current by resistance programming or voltage programming. Resistance programming in constant voltage is approximately 200 ohms per volt. Resistance programming in constant current is approximately two ohms per ampere.

Cooling: Internal fans provide forced air cooling of heat producing components.

Size: 14"H x 18-1/4"D x 19"W (standard relay rack mounting).

Weight: 239 lbs. (approximately).

Finish: Light gray front panel with dark gray case.

SECTION I.
GENERAL INFORMATION

1-1 DESCRIPTION

1-2 The H-Lab Model 6456A DC power supply is a completely solid state regulated power supply. It will supply up to 32 volts at up to 100 amperes with continuous adjustment of both voltage and current throughout the output range. The current limit can be set at any current from zero to 100 amperes to protect load elements at any predetermined current level.

1-3 Two meters measure load current and load voltage at the output terminals of the supply. Protection circuits incorporated in this supply are designed to protect the unit against overload conditions generated by the load device and failures in the input power line, while protection against failures in the internal main power mesh is accomplished by means of the three phase circuit breaker on the front panel. The breaker also serves as the on-off switch for the supply.

1-4 Input power is connected by means of a four-prong lock type connector at the rear of the unit. Output power connections and programming connections for the various modes of operation are also made at rear of the unit. The output terminals consist of heavy bus bar connected directly to the output capacitors for improved high frequency performance.

1-5 The programming terminals located at the rear of the unit allow the easy adaptation to remote sensing of the output voltage, remote programming of both output voltage and current, and to auto-series and auto-parallel modes of operation.

1-6 COOLING EQUIPMENT

1-7 The operation of this unit under high load conditions requires that air be circulated through a compartment containing the heat-producing elements in the circuit. This circulation is by means of fans located in the compartment with air flowing from one side of the unit to the other. Maintenance procedures concerning this cooling system will be found in the maintenance section.

1-8 EQUIPMENT SUPPLIED

1-9 The equipment supplied consists of only the Model 6456A DC power supply as this supply is complete in itself.

SECTION II
PREPARATION FOR USE

2-1 UNPACKING AND MECHANICAL INSPECTION

2-2 Inspect the instrument for signs of damage incurred in shipment. This instrument should be tested as soon as it is received. If it fails to operate properly or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent and this report should be forwarded to Harrison Laboratories. Harrison Laboratories will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. Include model number and serial number when referring to this instrument.

2-3 Harrison Laboratories warrants each instrument manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing and adjusting any instrument returned to the factory for that purpose and to replacing any defective parts thereof. Any damage to the instrument upon receipt is due to the carrier. File a claim with the carrier as instructed in the preceding paragraph.

2-4 LINE POWER

2-5 Because of the variety of line power connectors for three phase power sources, a power cord is not supplied but a twist lock type of connector that mates to the input power receptacle on the unit will be shipped with each new unit. The power cord and the plug for connection to the power source will be supplied by the buyer. Input line current is fifteen amperes maximum for a 208VAC line, dictating each conductor be at least number 14 gauge wire.

2-6 The AC power source to this supply may be either delta or wye with isolated neutral.

2-7 The SCR-3 series * as shipped, is wired for 230 volts AC $\pm$10%, three phase, 60 cps. 208VAC $\pm$10%, three phase, 60 cps may be accommodated by changing the strapping configuration on the input transformer. Refer to section 5 for details on this change. The unit can be wired by the factory for 208VAC, or 460VAC $\pm$10% 60 cps, when specifically requested by the buyer in his original purchase contract.

2-8 PREPARATION FOR STORAGE AND SHIPMENT

2-9 The best method of packing the instrument is in the original shipping carton with the original fillers packed in the same manner as received from the factory. Therefore, when unpacking note carefully the method of packing and save the original packing material for possible future reuse.

*Models 6450, 6453, 6455, 6456, 6459A'S

SECTION III.
OPERATING INSTRUCTIONS

3-1 PRELIMINARY CONSIDERATIONS

3-2 Check the strapping pattern on the rear terminals for the proper connection of the rear. Make sure that all binding head machine screws on the rear barrier strip are tight. Many troubles can arise if these straps are not making connection. Determine the type of operation as shown in Figure 3-1 and make certain that the rear barrier strip straps are connected for the operation desired. The power supply as furnished from the factory has a strapping arrangement as shown in Figure 3-1 entitled "Normal Strapping Connections."

3-3 CONNECTIONS TO LOAD

3-5 Load is applied to rectangular bus bars at the rear. The upper bus is positive.

3-5 Sensing is accomplished at rear terminals of the power supply as shipped from the factory. The user should be cognizant of the voltage drop which will occur in load leads, and minimize the drop by using large size cable and minimizing the load length to the load. Regulation at the load can be maintained within the specifications of the power supply by using remote sensing as described in this section of the manual.

3-6 CONSTANT CURRENT

3-7 The constant current circuit in the SCR-3 series serves two purposes. It protects the power supply and load, and it allows the supply to act as a constant current power source. If only a coarse current limit is required, the current control knob can be set somewhat above the point at which the supply will switch into constant current operation and be controlled by the current knob. In instances where the current limit need be set more precisely, the following procedure should be followed:

1. Turn the VOLTAGE and CURRENT controls full counterclockwise.
2. Place a short circuit across the output terminals of the supply.
3. Slowly rotate the VOLTAGE control clockwise about one-half turn.
4. Bring up the CURRENT control until the output current as read on the front panel meter reads the desired value of current.
5. Rotate the VOLTAGE control counterclockwise, remove the short circuit, reapply the normal load, and adjust the output voltage to the desired setting.

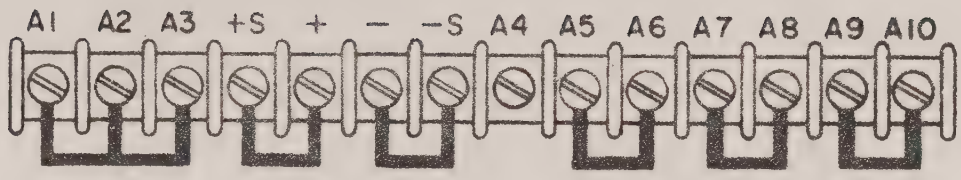


FIG. 3-1 NORMAL STRAPPING CONNECTIONS

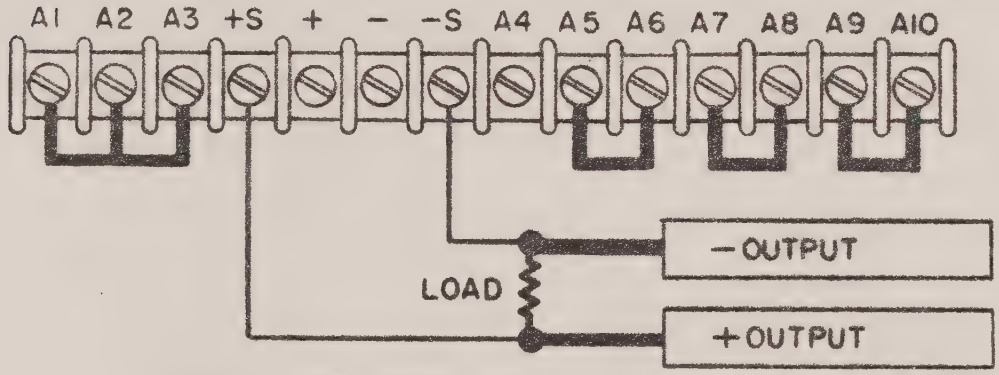


FIG. 3-2 REMOTE SENSING

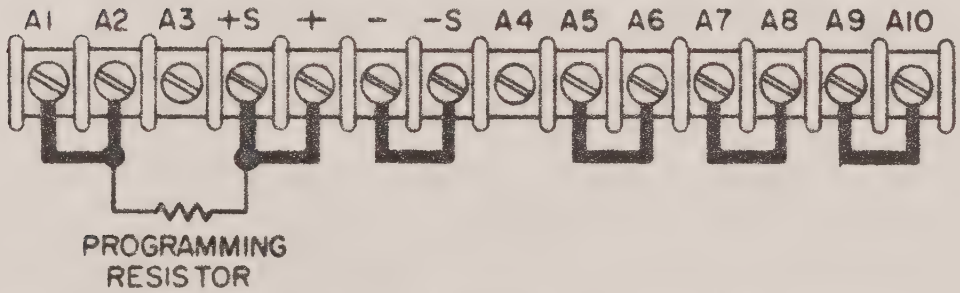


FIG. 3-3 REMOTE PROGRAMMING, CONSTANT VOLTAGE
(RESISTANCE PROGRAMMING)

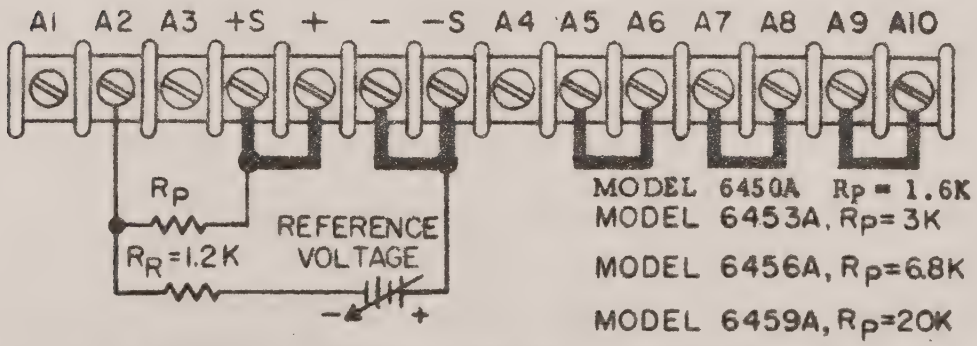


FIG. 3-4 REMOTE PROGRAMMING, CONSTANT VOLTAGE
(VOLTAGE PROGRAMMING)

3-8 When operating in the constant current mode, the voltage control can be adjusted for overvoltage protection.

3-9 REMOTE SENSING (See Figure 3-2)

3-10 In cases where the load device is remote from the power supply, resulting in poor load regulation at the load terminals, remote sensing can be used. As shipped, the power supply senses the output voltage at the output terminals of the supply and any IR drop in the leads between the power supply and the load causes a consequent degradation of the regulation at the load terminals. By sensing the output voltage at the load device terminals, these IR drops are effectively eliminated. The procedure for sensing the load at a remote location is as follows:

1. Turn off the front panel circuit breaker and remove the power cord from the power source.

2. On the barrier terminal strip on the rear of the unit remove jumpers (+S to +) and (-S to -).

3. Connect a pair of leads (#20 gauge wire) between +S and the positive terminal of the remote load and between the -S terminal of the supply and the negative terminal of the remote load.

4. Reconnect the AC power and turn on the power supply.

NOTE: The maximum IR drop that can be contained in the negative bus by means of remote sensing is one volt.

3-11 Although the use of remote sensing improves the DC load regulation at the load, it is important to note that the AC impedance at the load terminals is no better than it was with local sensing. In order to bring about an improvement in the AC impedance, it is advisable to place a large electrolytic capacitor across the terminals of the remote load.

3-12 REMOTE PROGRAMMING -- CONSTANT VOLTAGE

3-13 The power supply may be programmed from a remote location by means of an external resistance or an external voltage. It is necessary to change the strapping pattern on the barrier strip at the rear.

A. Resistance Programming (See Figure 3-3)

(1) A stable, low noise, low temperature coefficient programming resistor is recommended.

(2) The programming resistor takes the place of the front panel potentiometer.

(3) The output voltage will vary at a rate determined by the programming coefficient -- 200 ohms per volt (i.e., the output voltage will vary 1 volt for each 200 ohms connected across the programming terminals). The programming coefficient is determined by the programming current. The current is adjusted to within 0.5% of 5.0 milliamperes at the factory. If greater programming accuracy is required, it may be achieved by changing the shunt resistor, R8.

B. Voltage Programming (See Figure 3-4)

(1) A stable, low noise, low temperature coefficient programming resistor is recommended.

(2) $R_r = 1.2K$

$R_p = 6.8K$ or this resistor need not be used if the front panel C. V. potentiometer is left connected and set at 6.8K.

(3) The output voltage will vary linearly as the reference voltage is changed.

(4) For $R_r = 1.2K$, $R_p = 6.8K$; the reference voltage in going from zero to -6 volts will change the supply output voltage from zero to 32 volts. The maximum load on the reference voltage will be 5 milliamperes.

3-14 REMOTE PROGRAMMING -- CONSTANT CURRENT

3-15 The power supply may be programmed from a remote location by means of an external resistance or an external voltage. It is necessary to change the strapping pattern on the barrier strip at the rear.

A. Resistance Programming (See Figure 3-5)

(1) A stable, low noise, low temperature coefficient programming resistor is recommended.

(2) The programming resistor takes the place of the front panel potentiometer.

(3) The output current will vary at a rate determined by the programming coefficient -- approximately two ohms per ampere (i.e., the output current will vary one amp for each two ohms connected across the programming terminals). The programming coefficient is determined by the programming current. As a protection feature, the actual programming current has been set by the factory by turning the front panel current control potentiometer (250 ohms) full C.W. and adjusting shunt R22 for a maximum current limit of 110 amperes.

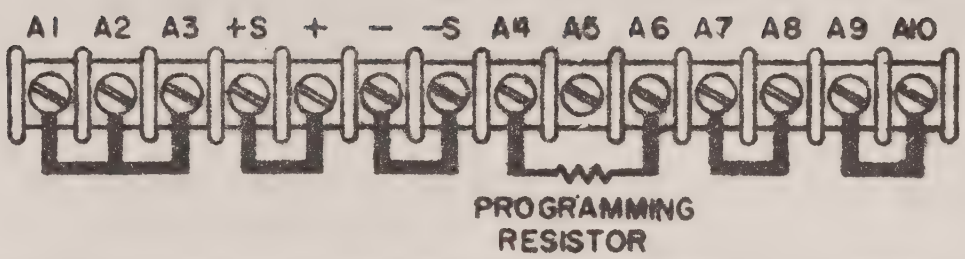


FIG.3-5 REMOTE PROGRAMMING, CONSTANT CURRENT
(RESISTANCE PROGRAMMING)

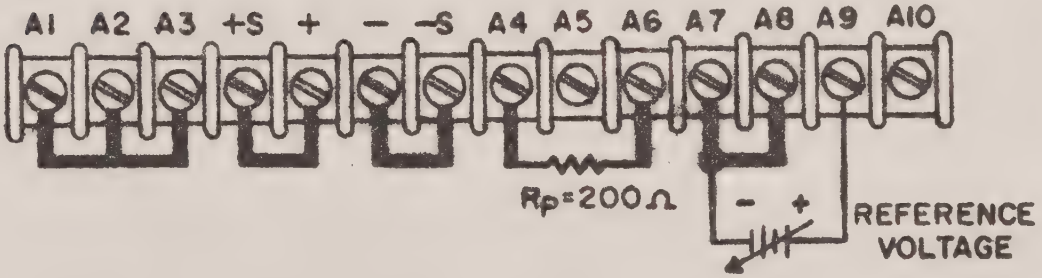


FIG.3-6 REMOTE PROGRAMMING CONSTANT CURRENT
(VOLTAGE PROGRAMMING)

This ratio, taking into account the offset voltage of the constant current differential amplifier, sets the coefficient at approximately two ohms per amp. If greater programming accuracy is required, it may be achieved by reshunting R22 terminals.

B. Voltage Programming (See Figure 3-6)

(1) A stable, low noise, low temperature coefficient programming resistor is recommended.

(2) R_p = 200 ohms or this resistor need not be used if the front panel current potentiometer is left connected and set maximum C.W.

(3) The output current will vary linearly as the reference voltage is changed.

(4) For R_p = 200 ohms; the reference voltage in going from zero to +6 volts will change the supply output current from zero to 100 amperes. The maximum load on the reference voltage will be 1.8 milliamperes.

3-16 AUTO-SERIES

3-17 For higher voltages, two or more Model 6456'S may be stacked with the positive bus of one tied to the negative bus of the next. Control of all supplies by a single voltage control is enabled by the addition of one control lead, as shown in Figure 3-7. With this connection, the "Master" supply becomes the reference voltage for the others, which have had their internal voltage references disconnected (a new fixed resistor is added). The slave supplies, set individually to any voltage, will track the Master voltage proportionally.

3-18 Wiring instructions for the connection of two supplies are illustrated in Figure 3-8. The VOLTAGE control of the slave must be set off zero at all times.

3-19 Where one load is connected across the output of series connected units (either end of the ensemble grounded), the current limit of the master should be used to control the current limit point of the ensemble. With the configuration providing dual voltages to independent loads, each unit has its own current limit point as programmed at the front panel CURRENT control but the output voltage of the slave will be proportional to the master output voltage.

3-20 The load regulation and line regulation characteristics of two or more 6456A's connected in series will be approximately the sum of the figures for each unit in the ensemble. Transient response should be approximately that of a single unit (50 milliseconds for a change in load from one half to full load).

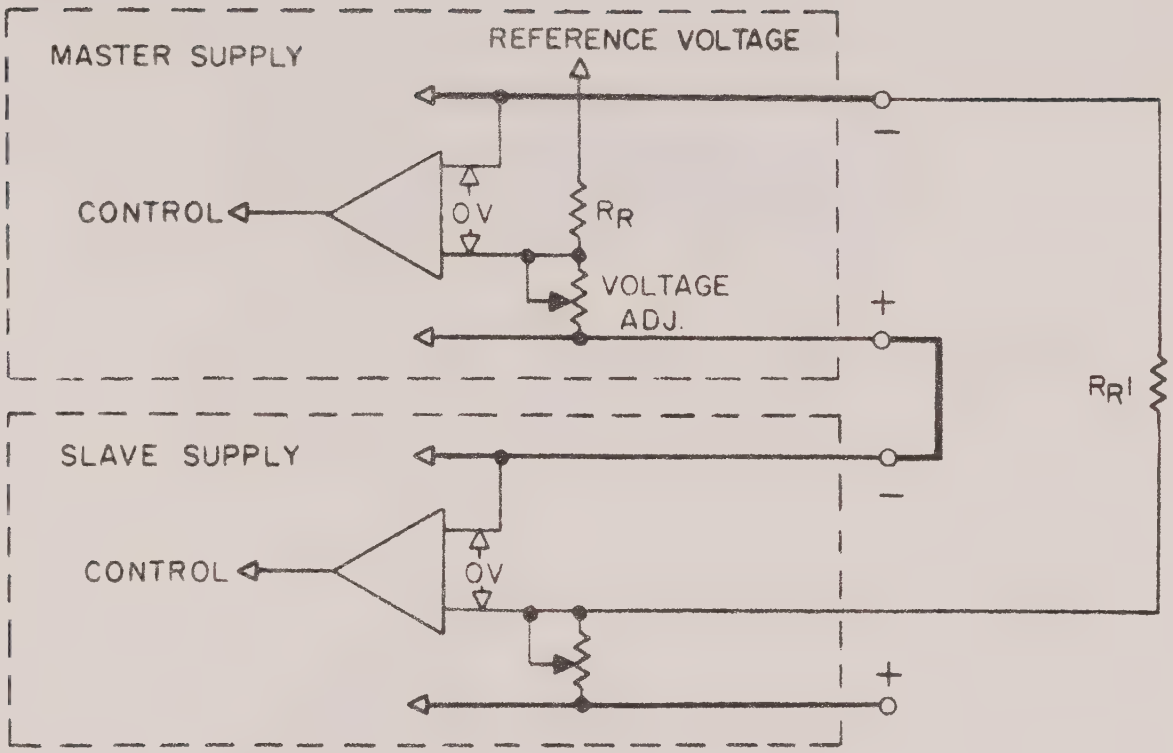
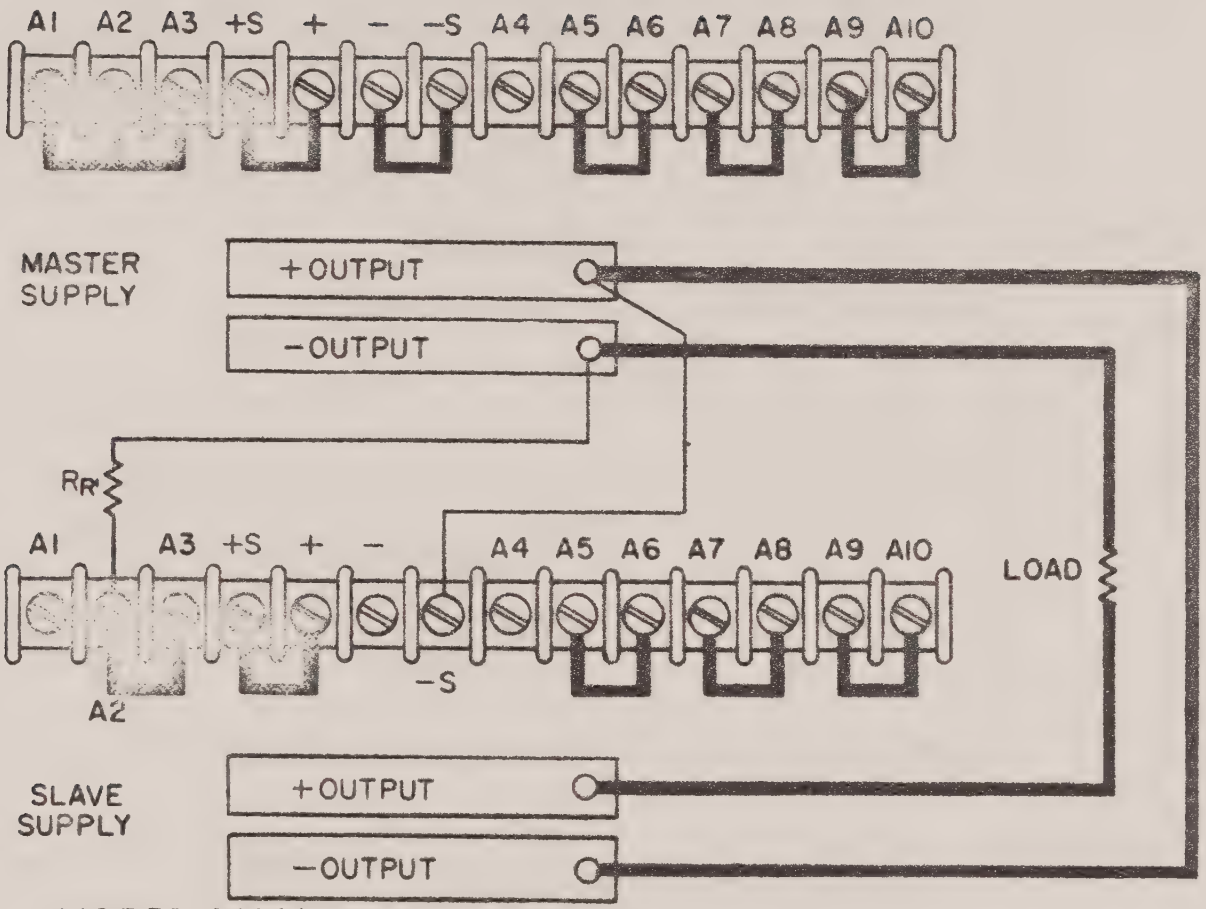


FIG.3-7 AUTO-SERIES DIAGRAM



MODEL 6450A R_R' = 1.6K
MODEL 6453A $R_{R'}$ = 3K
MODEL 6456A $R_{R'}$ = 6.8K
MODEL 6459A $R_{R'}$ = 20K

FIG. 3-8 AUTO-SERIES WIRING

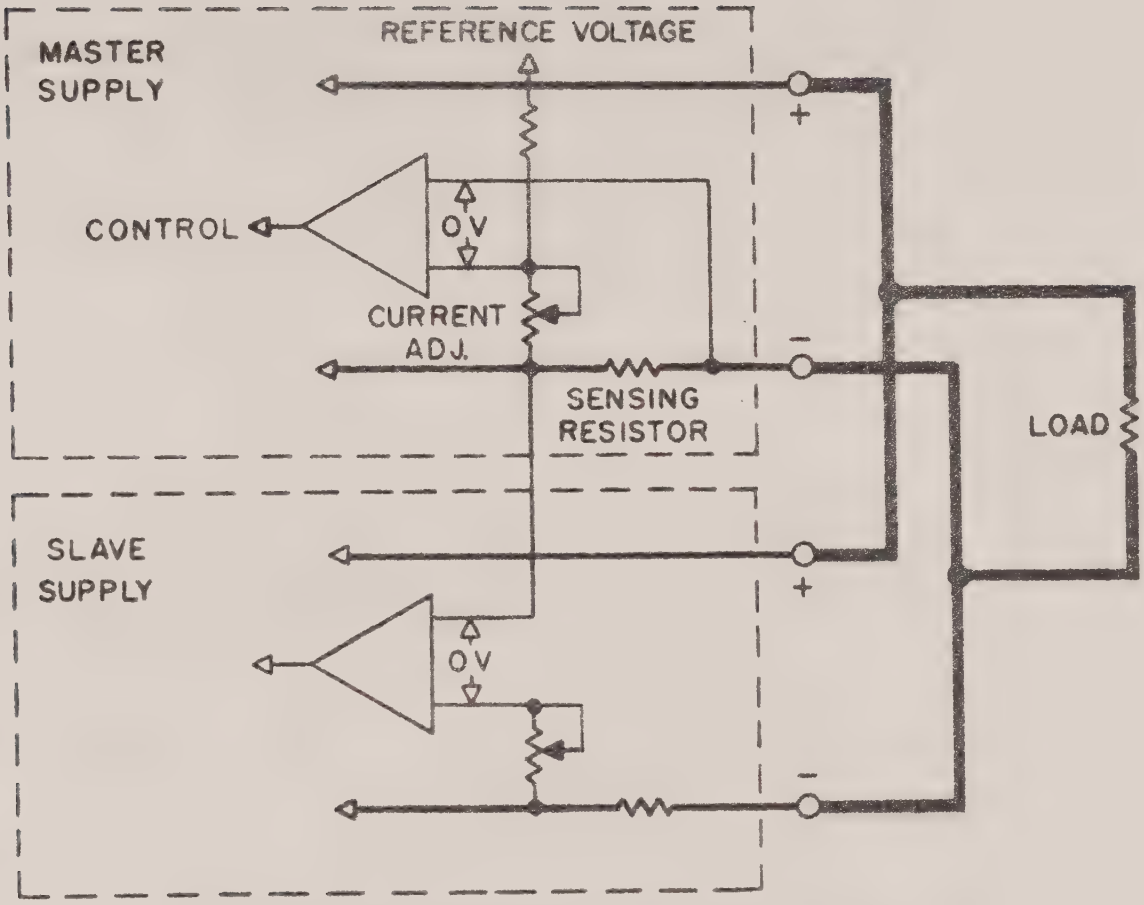
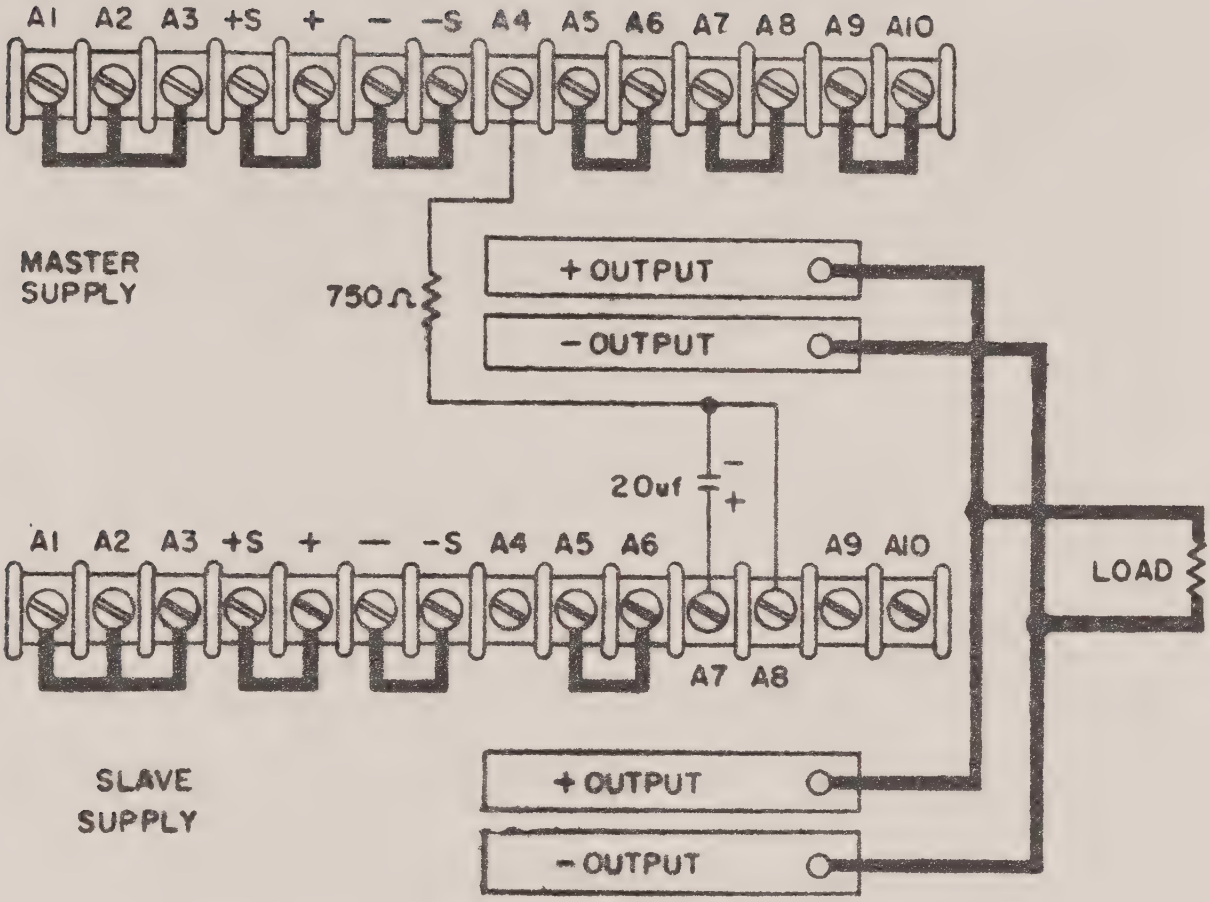


FIG. 3-9 AUTO-PARALLEL DIAGRAM



NOTE: KEEP WIRE LENGTH FROM EACH SUPPLY TO LOAD OF EQUAL LENGTH AND SIZE.

FIG. 3-10 AUTO-PARALLEL WIRING

3-21 AUTO-PARALLEL

3-22 Two or more power supplies may be connected in parallel for higher load current requirements with control of the output voltage and current retained in one of the units (Master). In this configuration the maximum current capabilities of the ensemble is within 10% of the sum of the maximum current capabilities of the units so connected. The constant current differential amplifiers of the slave supplies are disconnected from their own references and reconnected as shown in Figure 3-9. Each slave differential amplifier adjusts its current output so the voltage drop across its current monitoring resistor matches that across the current monitoring resistor of the master supply. Wiring instructions for the connection of two supplies are illustrated in Figure 3-10.

3-23 BATTERY CHARGING

3-24 The automatic transition between constant voltage and constant current displayed by the SCR-3 series makes it an ideal supply for battery charging applications. Using this feature, a battery may be charged at a constant current until the maximum charge voltage is reached at which point the supply will revert to constant voltage and continue to supply a trickle charge current sufficient to maintain full charge (See Figure 3-11). Thus, the charging operation can be unattended after properly setting the charging rate and the maximum charge voltage and connecting the battery to the output terminals of the supply.

3-25 The procedure for setting the charging rate and full charge voltage on the Model 6453A is as follows:

1. Turn both the VOLTAGE and CURRENT controls full counterclockwise.

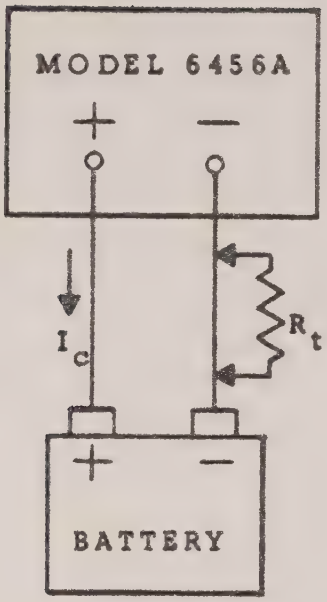
2. Place a short circuit across the output terminals and rotate the VOLTAGE control one half turn clockwise.

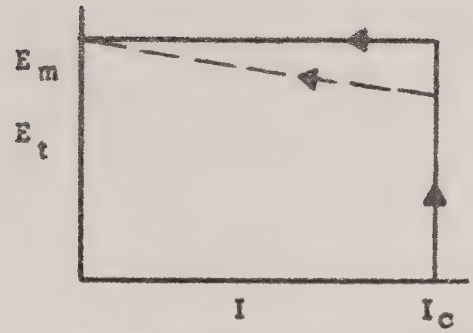
3. Rotate the CURRENT control to the desired charging rate as read on the front panel ammeter.

4. Rotate the VOLTAGE control full counterclockwise and remove the short circuit.

5. Rotate the VOLTAGE control to the desired full charge voltage as read on either the front panel voltmeter or a more precise voltage standard. The unit may then be connected to the battery terminals, positive to positive and negative to negative.

3-26 By inserting a small resistance in series with one of the load leads from the supply to the battery, it is possible to alter the normally rectangular charging plot (Figure 12) in such a manner as to provide a taper charge for the last portion of the charge cycle. The value of this resistance is the difference between the full charge voltage and the voltage at which the tapering is to start, divided by the maximum charging current.





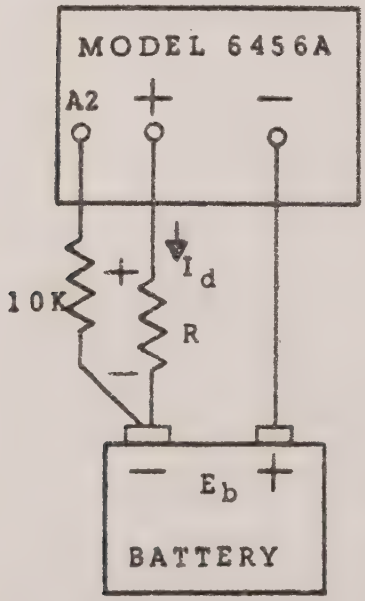
E_m = BATTERY FULL CHARGE VOLTAGE

I_c = CONSTANT CHARGE CURRENT

E_t = BATTERY VOLTAGE AT WHICH CHARGE RATE WILL BEGIN TO TAPER (WITH INSERTION OF R_t)

$$R_t = \frac{E_m - E_t}{I_c}$$

FIG. 3-11 BATTERY CHARGING



REMOVE JUMPERS A1 TO A2, A2 TO A3

I_d = DISCHARGE CURRENT

$$R = \frac{E_b}{I_d} \text{ BUT } RI_d \leq 32V$$

FIG. 3-12 BATTERY DISCHARGING

3-27 BATTERY DISCHARGING

3-28 Automatic constant current, unattended discharging of a battery using the SCR-3 seriesrequires certain changes in the strapping configuration on the rear barrier strip as illustrated in Figure 3-12. These changes are the removal of the jumpers from A1 to A2 and from A2 to A3 and the connection of A2 to the negative terminal of the battery through a 10K resistor. Make sure that the interconnecting leads between supply and battery are secure and cannot become opened.

3-29 The supply initially operates in constant current mode at the value set by the current control. When the battery voltage is high the supply output voltage will be low, and as the battery discharges the supply output voltage increases. A constant voltage is maintained across R (constant current throughR). This condition will prevail until the battery voltage drops to zero. At this point, the supply will switch off and no more current will flow through R.

3-30 The procedure for the connection of the components in this configuration is as follows:

1. De-energize the power supply and rotate the current control full counterclockwise. (The voltage control will be disconnected by step 2.)

2. Remove the designated jumpers (A1 to A2, A2 to A3) and connect A2 to the negative terminal of the battery.

3. Connect the negative terminal of the supply to the positive terminal of the battery.

4. Insert R between the positive terminal of the supply and the negative terminal of the battery, energize the supply and rotate the current control to the desired discharge current as read on the front panel meter.

3-31 MULTIPLE LOADING OF A POWER SUPPLY

3-32 It is imperative that each load have two separate leads brought directly back to the power supply terminal when connecting several pieces of equipment or subassemblies to the same power supply if full advantage is to be taken of the low impedance of the supply and mutual coupling effects between the equipment being powered are to be avoided.

3-33 AUTOMATIC CROSSOVER

3-34 There will be a time during which both the constant voltage input transistor and the constant current input transistor will be conducting. This will occur when the power supply has been operating in the constant voltage mode of operation and is overloaded or when the power supply has been operating in the constant current

mode of operation and the load is changed so that the output voltage reaches the voltage ceiling threshold. When operating in this crossover region, the regulation of the principal mode can be degraded. To prevent this, the control should be set to provide a margin of operation.

3-35 The current threshold should be set a minimum of 10 amperes greater than the maximum load current when operating in the constant voltage mode of operation.

3-36 The voltage threshold (open circuit voltage) should be set a minimum of two volts greater than the maximum operating output voltage when operating in the constant current mode of operation.

3-37 MEASURING THE PERFORMANCE OF THE POWER SUPPLY

3-38 The measuring device (differential voltmeter, digital voltmeter, or oscilloscope) must be connected to the output terminals as close as possible to the supply when measuring the output impedance , transient response, regulation, or ripple of the power supply in order to achieve valid measurements. It is important that none of the output current flows through the lead lengths in series whith the monitoring device since such lead lengths can easily have an impedance of the same order of magnitude as the supply impedance and thus effectively invalidate the measurement.

3-39 Connect either the positive or negative terminal of the supply to the chassis ground and the scope case to the same point, making certain that the scope case is not also grounded by some other means such as the power cord when measuring the power supply ripple. Connect both scope leads simultaneously to the power supply ground terminal to be doubly certain that the scope is not exhibiting a ripple or transient spike that is not coming from the power supply.

3-40 It is recommended that a four-terminal resistor be used to make constant current measurements.

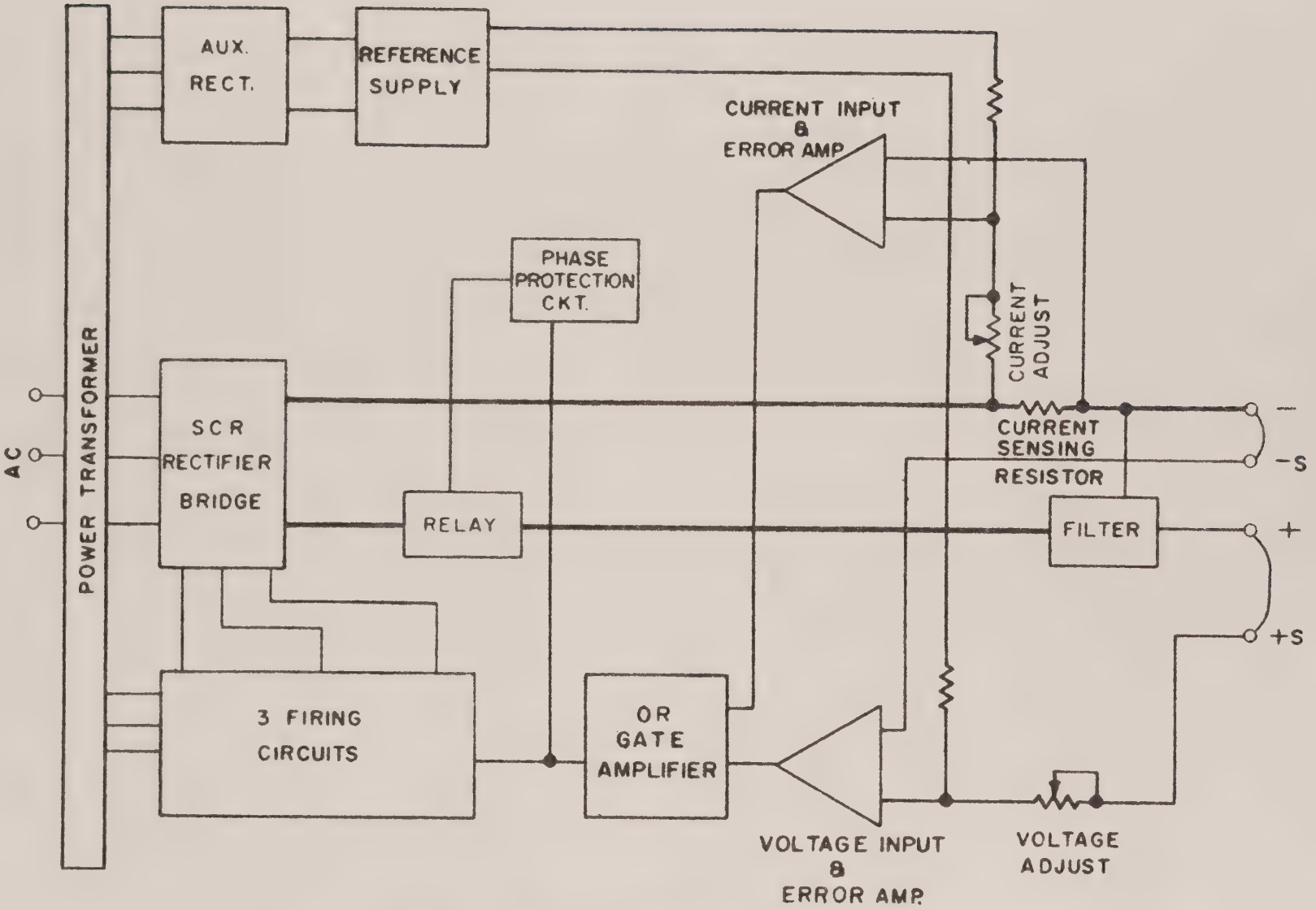


FIG. 4-1 BLOCK DIAGRAM

SECTION IV.
PRINCIPLES OF OPERATION

4-1 BLOCK DIAGRAM

4-2 The block diagram, Figure 4-1, shows the basic parts of the power supply. The line voltage is transformed by the three phase power transformer to the bridge rectifier circuit containing both fixed rectifiers and silicon-controlled rectifiers. The SCR turn-on firings are controlled in such a manner as to supply the desired output voltage and current. Separate windings on the power transformer furnish three phase voltage to the auxiliary rectifier for the bias supply and furnish three phase voltage for the three firing circuits to operate on.

4-3 The DC current passes through the current sensing resistor connected in the negative bus. The voltage developed across the sensing resistor is the input to the current input amplifier. The output voltage of the power supply is monitored by the voltage input amplifier through the sensing terminals (+S and -S). Any changes in output voltage/current are detected in the constant voltage/current input amplifier, passed through the "or" gate, and applied to the firing circuits. The firing circuits control the SCR firing to counteract the change.

4-4 The "or" gate implements the constant voltage/constant current crossover operation of the supply. It allows one or the other amplifier signal to pass and control the loop but not both at once. The more restrictive signal, demanding less power output, is the controlling signal.

4-5 SIMPLIFIED SCHEMATIC

4-6 The simplified schematic, Figure 4-2, shows the various voltages used throughout the supply. The ammeter location, across the current sensing resistor R96, and the voltmeter location, across the output terminals of the power supply are shown. C12-C17 across the output are the filter capacitors and together with choke L1 form the power filter. CR10 is a (F.W.D.) free wheeling diode acting in conjunction with the choke. Also, it protects the power supply if a reverse voltage is applied across the output terminals.

4-7 R97, R98, and CR61 function as a voltage ceiling circuit. When the output voltage at the positive terminal reaches the ceiling level CR61 turns on, introducing a positive hold signal to the current input amplifier. Another protection feature is the phase protection circuit which stops operation if an input AC line phase opens or the line voltage drops below normal. The circuit samples the three input phases (from three diodes not shown in the simplified schematic) and in the event of failure turns off the control signal to the firing circuits and then opens power relay K1. When the input returns to normal, the relay is closed and firing pulses resume.

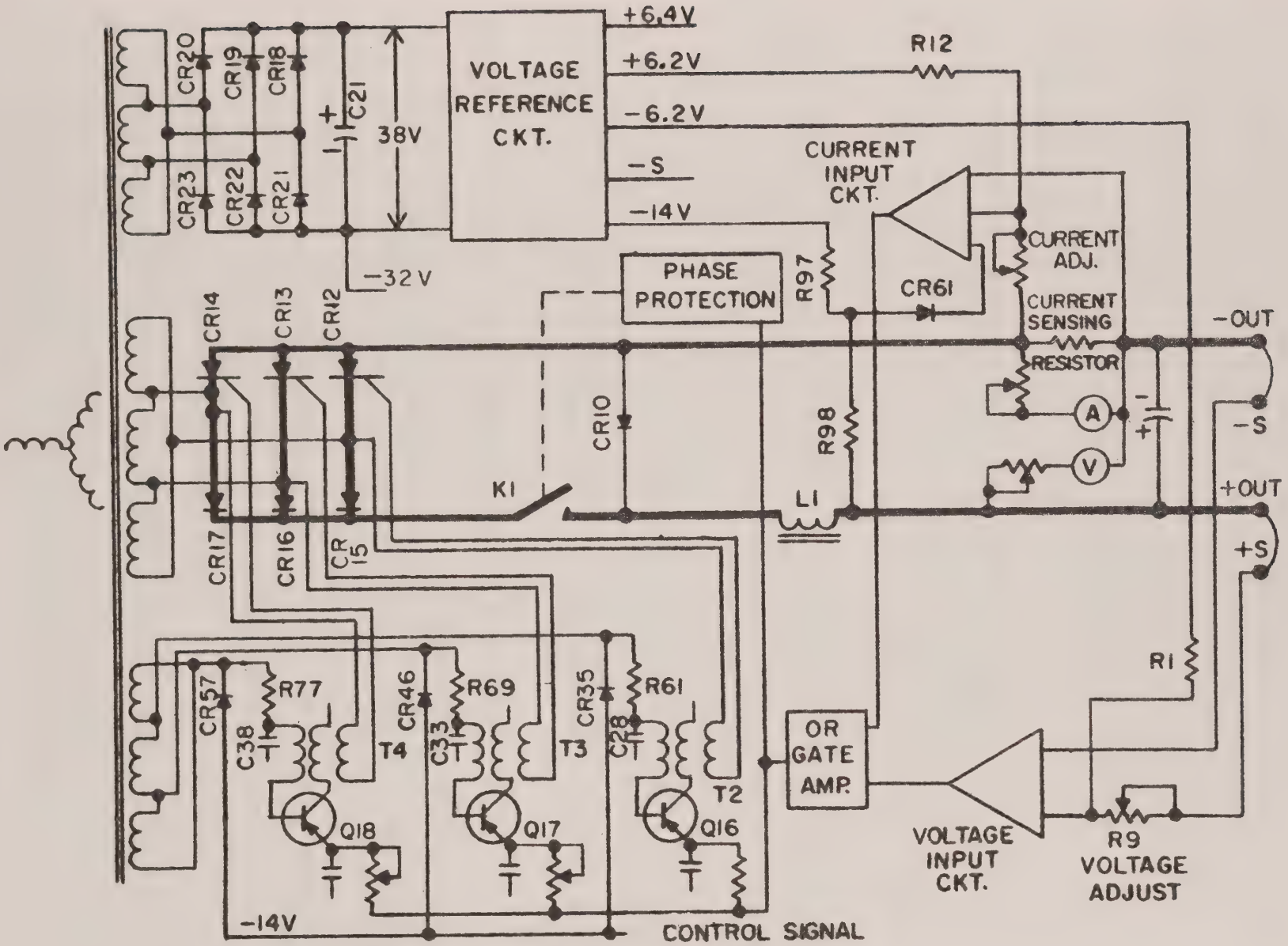


FIG. 4-2 SIMPLIFIED SCHEMATIC

4-8 The function of the constant voltage input differential amplifier is to compare the reference voltage with the output voltage and to generate a correction signal if the output deviates from its prescribed value. One input to the amplifier is grounded to the negative output terminal -S while the other input is the summing point of output voltage and the -6.2VDC reference voltage. When no error exists zero volts is maintained between the amplifier input terminals. Any change in output voltage, whether it is due to a change in the setting of the front panel potentiometer or perhaps due to a change in load current tends to produce a voltage other than zero at this second input terminal. Feedback loop action thereafter is such as to reduce this error to zero.

4-9 The action of the constant current input amplifier is similar to the constant voltage amplifier. The current sensing resistor, which monitors the output current, is a strip resistor located in the air blast alongside the main heat sink. Four terminal connections are made to it, one sensing terminal constituting the reference for the constant current loop, the other the signal terminal going to the amplifier.

4-10 The three firing circuits receive the output of the or gate amplifier, mix this with an AC bias provided by the bias transformer windings, (this allows instantaneous correction for changes in line voltage) and generate firing pulses that turn on the silicon-controlled rectifiers in their respective phases at the precise time necessary to fulfill the feedback loop requirements. As can be seen in Figure 4-2, everything is done in triplicate. For each phase there is a transistor blocking oscillator with the third winding of the blocking oscillator transformer providing the gate pulse to the SCR gate leads. The three bias transformer windings are delta connected and the leads brought out to diodes CR35, CR46, and CR57. These diodes perform half wave rectification of the AC voltage. Thus, the voltage waveforms to input resistors R61, R69, and R77 are the same phase and shape as the waveforms across the SCR's in the main rectifying bridge.

4-11 MAIN RECTIFYING AND FILTERING CIRCUITS (See Figure 5-1)

4-12 Three phase 230VAC 60 cps line voltage is connected to the primary of transformer T1 through a three phase common trip type circuit breaker which serves the dual function of ON/OFF control and protection against failure in the main power mesh. The wiring on the primary of the transformer may be changed to accommodate three phase 208VAC, or 460VAC as outlined in the maintenance section. The primary is Wye connected with isolated neutral. The 208VAC taps to neutral are used to power the fans and the front panel power indicator light. The three main secondary windings are delta connected to a threephase fullwave bridge consisting of three SCR's (CR12, 13, 14) and three fixed rectifiers (CR15, 16, 17). The positive DC output side is the rectifier heat sink. The heat sink is cabled to the relay, then choke, and then to the filter capacitor bank +(C12 through C17). The negative DC output side is the SCR heat sink. The sensing resistor is located on the heat sink as its output terminal, and from it cabling connects to -(C12 through C17). The firing angle of each SCR is controlled in such a manner as to fulfill the load conditions on the output terminals of the supply dictated by the output voltage/current setting and the load resistor. Resistor R60 provides a bleed path for the discharge of the filter capacitors at no load.

4-13 CR10 is the free wheeling diode (F.W.D.) rectifier. It has a reverse polarity rectifier case and is located in the SCR heat sink so its cathode can be connected after the relay on the positive output.

WARNING: MAKE SURE REPLACEMENT FOR CR10 IS A REVERSE POLARITY RECTIFIER.

4-14 The F.W.D. conducts, carrying the choke current, for the parts of each cycle when no SCR is conducting, and therefore conducts under every condition except full power output. Due to the action of choke and F.W.D. the SCR couduction angle, at short circuit full current output, is small and the input AC RMS line current is approximately one half that at full power. Also, CR10 protects the output capacitors in case a reverse voltage is applied on the output terminals. (Such a case can occur in auto-series operation when the slave unit is de-energized while the master unit is energized.)

4-15 REFERENCE CIRCUIT (See Figure 5-1)

4-16 Three phase fullwave bridge windings 3, 4 on transformer T1 provide power for the auxiliary and reference voltages. Diodes CR18 through CR23 and capacitor C21 provide an unregulated -32VDC (test point 20). All voltages are measured with respect to -S. The positive side of this unregulated auxiliary voltage is returned to +6.4VDC.

4-17 Resistors R49,R50, R51, Zener diode VR3 and transistor Q14 form a shunt regulator whose output is a -14VDC (T. P. 12). In this configuration resistor R49 provides a constant bias current for VR3 (a 20 volt zener diode). Any voltage variation across the shunt regulator is transmitted via the low impedance of VR3 to the base of the transistor. Q14 changes its collector current which is reflected in a voltage change across R51, reducing the variation. R50 reduces the power dissipation of Q14. C20 reduces ripple and causes a slow buildup of the -14 volts at turn-on. The line regulation of this -14 volt source is approximately $\pm$100 millivolts for an input line change of $\pm$10%.

4-18 R48, two 6.2 volt zener diodes VR1 and VR2, and Q13 are connected in series from -14VDC to +6.4VDC. VR1 and VR2 produce the two reference voltages +6.2VDC and -6.2VDC. Any changes in the -14VDC source are attenuated by the ratio of R48 to the forward impedance of the two diodes in series. Q13 acts as a shunt regulator for VR1, the base to emitter voltage and R47 determining the zener bias current There is a large variation in the current returning through +6.4VDC to -S from other parts of the circuit and this bypasses VR1 through Q13.

4-19 CONSTANT VOLTAGE INPUT AMPLIFIER (See Figure 5-1)

4-20 Transistors Q1 and Q2 form a differential amplifier for the purpose of error detection and amplification in the voltage mode. The inputs of this amplifier are the bases of the two transistors. The output is the collector of Q1. The base of Q2 is considered the reference base and is connected to -S through R5 to achieve good thermal compensation. R6, from the base to the -6.2VDC reference voltage, provides a slight negative bias voltage at the base to insure that the output of the power supply is adjustable to zero volts. The base of Q1 is connected to summing

point A2, which is the junction of current pullout resistor R1 and the front panel potentiometer R9. The control action continuously adjusts the output voltage on the positive bus to bring the voltage at A2 to the -S potential. With A2 held at the -S bus voltage, the voltage drop across R1 is the same as the reference voltage, and this voltage drop remains constant during operation. The current through R1, and thus through R9, likewise is held constant so that the IR voltage drop across R9 is determined solely by the resistance value of R9. Thus, the power supply output voltage is a linear function of the resistance of R9.

4-21 R2 in the base lead of Q1 limits the current through the programming resistance (pot) under conditions of rapid voltage turndown, and also isolates input and base for stabilizing the feedback loop. Diodes CR1 and CR2 limit voltage excursions on the base of Q1. Capacitor C1 bypasses the pot making the high frequency gain of the input circuit insensitive to pot setting. Capacitor C2 and adjustment pot R10 are located around the amplifier for loop stability.

4-22 CONSTANT CURRENT INPUT AMPLIFIER

4-23 Transistors Q4 and Q5 form a differential amplifier for the purpose of error detection and amplification in the current mode. The basic operation is the same as the constant voltage input amplifier. However, in the current case reference is with respect to the sensing terminal A7 of the sensing resistor R96. R20 at the base of Q5 is normally connected to this reference. The resistor R96 requires four terminals to keep the voltage drop along the internal connections of the power supply from the sensing resistor to (-) from contributing to the input signal. The following components of the constant current input amplifier have functions as described for the voltage input amplifier:

R19 -- Positive offset bias to base of Q5
CR5, CR6 -- Protection diodes
R13 -- Current limiting
C5 -- Stability
R24 -- Stability adjustment
R23 -- Front panel current control pot
R12 -- Current pullout resistor; sets programming current
R22 -- Shunts R12; used for trimming adjustment

4-24 Additional components are C4, CR4, and R14, and those associated with Q6. C4 reduces ripple voltage entering the amplifier. CR4 and R14 come from the Phase Protection Cutoff Circuit. Normally, the cathode of CR4 is +5.5VDC so the diode is cut off. Upon a phase failure, however, the voltage drops to approximately -28VDC at R14, CR4 turns on, and CR6 is clamped on by the one milliampere current. This negative signal shuts the supply off via the constant current loop. Q6 supplies one milliampere bias collector current to Q5 without shunting down the 47K load resistor R18. In this way, the DC gain of the constant current loop is increased. The bias current is fixed by the ratio of the forward voltage drop of CR7 and R17.

4-25 "OR" GATE AMPLIFIER (See Figure 5-1)

4-26 The OR gate receives signals from the two input amplifiers at the bases of Q8 and Q9. The most negative base signal tends to turn its transistor on harder. At the same time, the negative voltage is transmitted to the emitter and so to the emitter of the other transistor, turning it off. When the signal to either input amplifier increases above the level set by the control pot, the amplifier output moves negatively. This switches the OR gate and that amplifier controls the loop at its voltage/current setting.

4-27 The output of Q8/Q9 is amplified by Q10 to a suitable voltage level for controlling the firing circuits (test point 15):

Power supply OFF signal: Q10 saturated, -13VDC
Power supply just ON: -10VDC
Maximum power: +2VDC

4-28 Diode CR9 at the emitter of Q10 provides 0.7VDC bias voltage for the stage. Q11 is an emitter follower which transforms impedance so the firing circuit is driven from a voltage source.

4-29 An auxiliary feedback signal is connected from the input side of choke L1 (test point 14) to the base of Q10 via R28 and C8. Capacitor C9, to reference A7, performs three functions:

1. C9 reduces ripple appearing from the input L1;
2. C9 provides a frequency cutoff slope;
3. C9 causes a slow turn-on signal buildup to the firing circuits.

4-30 SILICON-CONTROLLED RECTIFIER FIRING CIRCUITS (See Figure 5-1)

4-31 GENERAL

4-32 The SCR is a solid state device which displays high impedance characteristics with either positive or negative voltage on its anode but which may be switched into a high conductance state when positive voltage is supplied to the anode simultaneously with a gate signal application between its gate lead and its cathode. The gate signal that is used to turn on the device in the SCR-3 series is a positive going pulse of about 50μ seconds duration and whose amplitude is approximately 3.5 volts, this being the output of the blocking oscillator.

4-33 Each of the input phases has an SCR and a firing circuit associated with it. Each firing circuit generates an output pulse for its SCR once each cycle of input line frequency and so timed that each SCR conducts at identically the same phase angle in its respective phase.

4-34 The input to the three firing circuits is the output of the OR gate amplifier (transistor Q11 emitter) and is as previously mentioned a DC voltage referenced to -S and varying in amplitude between +2 volts and -10 volts as a function of the output conditions. This voltage is applied to three identical ramp capacitors (C26, C31, C36) through resistances R60, R87, R68, R76, and R88. The relatively high voltage signal produces current in each resistor which is integrated by the ramp capacitors to produce a steadily rising ramp voltage. R87 and R88 are pots which are adjusted to balance or nearly balance the ripple voltage on the output of the power supply.

4-35 BLOCKING OSCILLATOR

4-36 A blocking oscillator is the firing circuit for each phase in the SCR-3 series. The blocking oscillators (T2, T3, and T4) are triggered into the conducting state by a transistor. Each output winding of the transformers (terminals 11 and 12-- test points 25,26,30, 31,35, 36) is connected between the gate and cathode leads of an SCR through a series current limiting resistor (R56, R64, and R72) with a diode connected in the reverse direction between gate and cathode of the SCR to prevent the possible appearance of a reverse spike or pulse on the gate of the SCR (CR26, CR37, and CR48).

4-37 The mechanism by which the blocking oscillator is triggered is by switching the transistor from the non-conducting state into the conducting state (transistor Q16, Q17, and Q18). The transistor has as its collector load one winding of the blocking oscillator transformer. Two windings are connected in series (for double voltage) in the base lead of the transistor. The base of the transistor follows the voltage of the base capacitor (C28, C33, and C38). The voltage on the emitter rises to meet the base at which time blocking oscillator action takes place. The start of current in the emitter of the transistor and the regenerative coupling that exists between the collector and base windings causes the transistor to go into saturation where it remains until the saturation region of the transformer is reached. At this point the coupling action collapses and the transistor returns to the non-conducting state.

4-38 Capacitors C25, C30, and C35 between the base and emitter prevent spurious triggering. Resistors R59, R67, and R75 in the base circuits limit the base current which flows during the blocking oscillator action. Upon conduction of the blocking oscillators, the ramp capacitors discharge negative with the emitter current and the base capacitors charge positive with base current. This prevents the blocking oscillator circuit from retriggering during that same cycle. At the end of the cycle these capacitors are reset for the next cycle.

4-39 FIRING ANGLE DETERMINATION

4-40 Determination of the proper firing angle is accomplished by mixing two signals in the blocking oscillator circuit, these two signals being a reflection of the output conditions and the input line conditions. A ramp voltage whose origin is

approximately -17VDC and whose slope is a function of output voltage and output current is subtracted from a halfwave rectified voltage whose amplitude is a function of the input line voltage.

4-41 The three phase bridge circuit providing voltage to the firing circuits consists of windings 5, 6 on the main transformer and diodes CR35, CR46, and CR57. This bridge provides the waveshape shown in Figure 5-2 to the firing circuits through R64, R69 and R77. R78 reduces the amplitude of the signal from R77 and C38 charges toward the positive peak. The integrating action of C38, along with diode CR55, provides a smooth voltage shape at C38 with the amplitude still a function of line voltage.

4-42 Line Compensation: If the input AC line voltage increases from nominal the voltage wave amplitude at C38, the base of Q18, increases. Then more time is taken for the ramp at the emitter to catch the base voltage and SCR firing is delayed. The decreased firing conduction angle compensates for the larger voltage available at the input.

4-43 RESET OPERATION

4-44 At the end of each line cycle the ramp capacitor and base capacitor are reset to their starting voltages and operation repeats. The resetting operation is performed by the positive going rectified wave referenced to -14VDC (See Figure 5-2), which is the input to the firing circuits at CR35, CR46, and CR57. These diodes with anode at -14VDC set the reference level by clamping. Diodes CR49, 50, 51, and 54 are always conducting; their bias current flows to the -32VDC through R73. Thus, the voltage at the cathodes of CR52 and 53 follow the input voltage from CR57. During the time that CR57 clamps, base capacitor C38 is held at about -15 volts by CR57, 54, and 53. C36 is held at about -17 volts by CR57, 54, 51, 50, 49, and 52. The two volt difference back biases the blocking oscillator transistor base to emitter junction. When the input voltage starts positive again, it rises rapidly; CR52 and 53 are cut off, and the base and emitter capacitors follow their input signals.

4-45 METERING CIRCUITS

4-46 Both voltmeter and ammeter circuits consist of a 1.0ma type movement with the calibrating resistors contained on the rear printed board. The voltmeter is connected across the output terminals and is calibrated by means of rheostat R111. The ammeter circuit is connected across the internal current monitoring resistor and is calibrated by means of rheostat R112.

4-47 PROTECTION CIRCUITS

4-48 One of the protection features incorporated in the SCR-3 series is the internal connection of 100 ohm resistors between the sensing terminals and the output terminals (R91 and R94). These resistors provide protection should the sensing lead become open (particularly when using remote sensing). These resistors insure that the output voltage will rise only slightly if a sensing lead should become open.

4-49 Another protection circuit incorporated into the SCR-3 series insures that no damage will occur internally should one or more of the input phases fail. This circuit monitors the input voltage and upon such a failure clamps the control signal off and then opens power relay K1. When the phase returns to normal, the operation reverses itself.

4-50 Diodes D36, D47, and D58 connected to the reset waveform of the three firing circuits and biased by resistor R105 connected back to the -32VDC provide at their juncture (test point 49), a signal composed by the full wave rectification of the input phases. With the presence of three phases on the input, the average voltage at T.P. 49 is positive enough to bias Q21 and Q20 ON. In the event of failure of one or more phases, the average voltage becomes negative and reverse biases Q21 which turns off Q20. CR63 provides a 0.7 volt reverse bias which Q21 overcomes to turn Q20 on. Q20 saturates, when on, holding its collector at +5.5 volts. The relay coil in series with R108 is then across the auxiliary supply voltage, holding the relay on. R102 and CR62 across the coil reduce the spike at turn-off.

4-51 The collector of Q20 is also connected to R14, and CR4 going to the constant current input amplifier, and to R37, going to the OR gate amplifier, to turn these off and on with the relay.

SECTION V.
MAINTENANCE

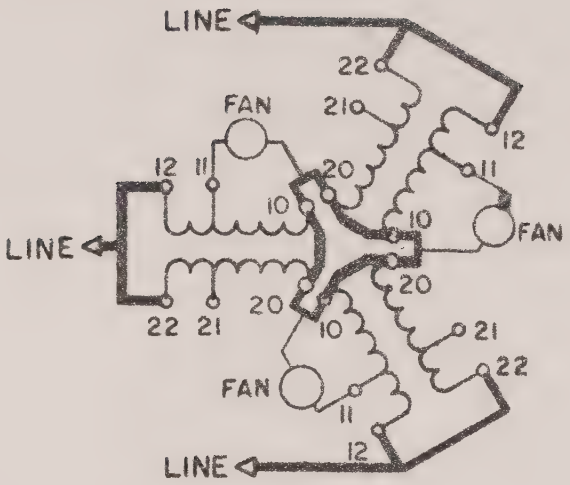
5-1 PERFORMANCE CHECK

5-2 EQUIPMENT REQUIRED

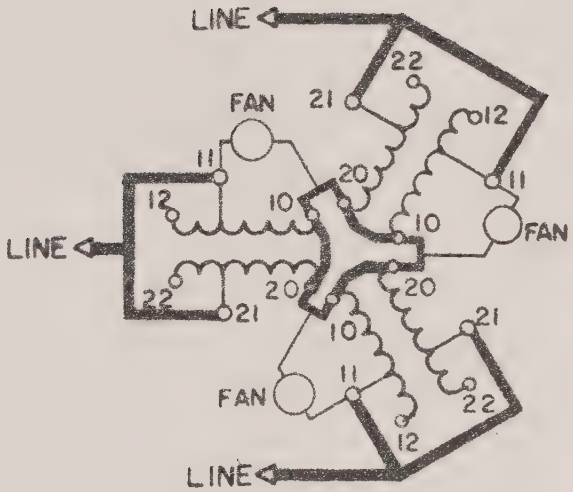
1. Line cord (4 wire) and plug for connection to 208/230/460VAC 3 phase, 60 cps source.
2. Oscilloscope.
3. 100 ampere shorting strap for output terminals.
4. Ohmmeter.

5-3 PROCEDURE

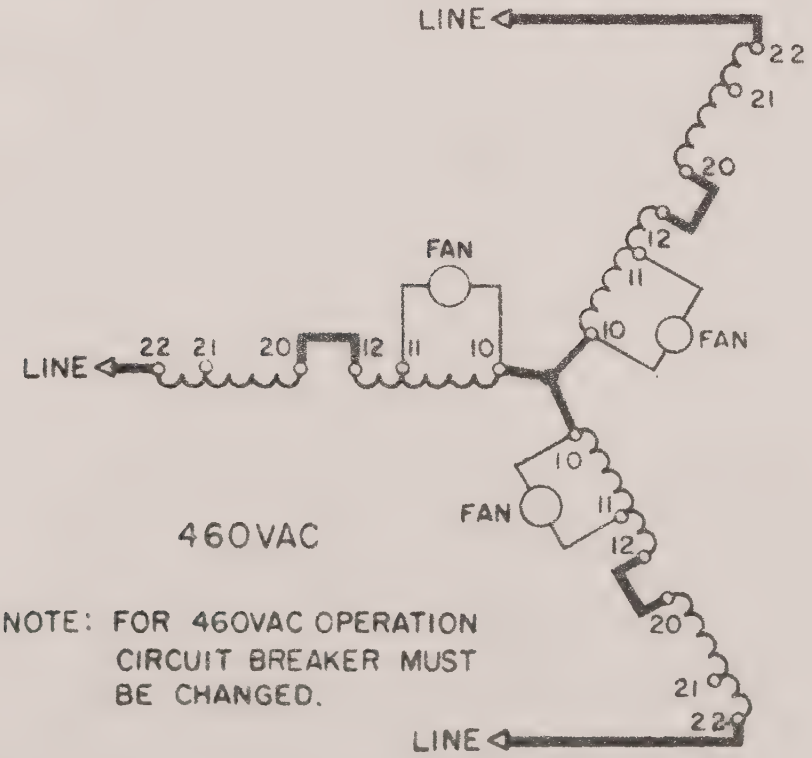
1. Measure the resistance to chassis ground from each output bus and from each phase pin on the AC power connector at the rear of the unit (pin with the locating lug is connected to chassis ground internally) with the front panel circuit breaker in the ON position. Measured resistance should be in excess of one megohm on all measurements.
2. Check the ammeter and voltmeter on the front panel for zero set. If alignment is required, refer to the MECHANICAL MAINTENANCE section.
3. Rotate the front panel VOLTAGE control full counterclockwise (OFF) and the CURRENT control full clockwise (ON). Check the programming terminal strip on the rear of the unit for normal strapping (see Figure 4). Place the front panel circuit breaker in the OFF position. Connect an oscilloscope to the output terminals using a 3 to 2 connector to connect the oscilloscope to the power source. Connect chassis ground to the negative output terminal. Set the vertical amplifier to AC coupling, 50mv/cm; horizontal to 2 milliseconds/cm sweep.
4. Connect the line cord to the power supply, then to the power source.
5. The first test is at no load. Place the circuit breaker in the ON position. Front panel meters should both read zero.
6. Rotate the VOLTAGE control full clockwise. Output voltage should be 36±2VDC as read on the front panel voltmeter (ammeter should still read zero). Turn down voltage to 32VDC. Output ripple should be approximately 25mv peak to peak and 180 cps (one peak each 5.5 millisec.). At no load the voltage decay on turn-down will be quite slow due to the 0.2 farad capacitor bank (with a 44 ohm shunt bleeder) within the supply.
7. Rotate the CURRENT control full counterclockwise. Insure that supply turns off.
8. Rotate the front panel VOLTAGE and CURRENT controls full counterclockwise, de-energize the unit, and place a shorting strap across the output.
9. Rotate the VOLTAGE control clockwise about one half turn. Rotate the CURRENT control ON controlling the current to maximum and back again, reading the front panel ammeter.



230 VAC



208 VAC



460VAC

NOTE: FOR 460VAC OPERATION CIRCUIT BREAKER MUST BE CHANGED.

FIG.5-2 TRANSFORMER PRIMARY WIRING FOR 208 / 230 / 460 VAC

10. Place the circuit breaker in the OFF position, rotate the VOLTAGE control counterclockwise. Remove the power cord from the power source and disconnect the short circuit across the output terminals.

5-4 POWER SUPPLY ADJUSTMENTS

5-5 METER ZERO-SETTING

5-6 The meter pointers must reset on the zero calibration mark on the meter scales when the instrument is at normal operating temperature, resting in its normal operating position and the instrument is turned off. To zero-set the meters proceed as follows:

1. Rotate adjustment screw on the front of the meter clockwise until the pointer is to the left of zero and further clockwise rotation will move the pointer up-scale towards zero.
2. Turn the adjustment screw clockwise until the pointer is exactly over the zero mark on the scale. If the screw is turned too far, repeat steps 1 and 2.
3. Turn meter adjustment screw counterclockwise about 15 degrees to break contact between adjustment screw and pointer mounting yoke, but not far enough to move the pointer back downscale. If screw is turned too far, as shown by the needle moving, repeat the procedure. The meter is now zero-set for best accuracy and mechanical stability.

5-7 208/230/460VAC OPERATION

5-8 To change the operation of the supply to another three phase 60 cycle voltage, the primary of the power transformer must be rewired, and for 460VAC operation the circuit breaker must be changed. Wiring for 460VAC operation should be done at the factory. Figure 5-2 shows the three phase Wye primary connections for the three voltages. Nothing else need be done to change operation.

5-9 MECHANICAL MAINTENANCE

5-10 COOLING SYSTEM MAINTENANCE

5-11 The SCR-3 series utilizes forced air cooling on the rectifiers and transformer. The rectifiers are located in the heat sink compartment on the top of the unit running the full width of the chassis. As in any forced air cooling system, the compartment should be cleaned regularly (regularity will depend on the cleanliness of the air in the surrounding area). Remove the top cover of the supply and the heat sink compartment and clean with either a vacuum cleaner or with compressed air. Regular cleaning maintains the efficiency of the heat sinks and reduces the possibility of a short circuit to ground due to particle build-up around the rectifiers.

5-12 The blower motor bearing surfaces should be lubricated every six months as another preventative maintenance procedure.

5-13 PRINTED CIRCUIT BOARD ACCESS

5-14 The printed circuit board in the SCR-3 series is located in the top rear of the chassis. Access to board may be accomplished by removal of the dust cover.

5-15 Removal of the dust cover provides access to the top (component side) of the board, but not to the bottom (copper side). The bottom of the board can be made accessible by removing the screws along the board and rotating out by its hinges. CAUTION: Do not work on printed circuit boards before AC plug is removed and output capacitors are allowed to completely discharge.

5-16 Check that all wires are connected to the board (after work is completed) before replacing the board in its normal position.

5-17 PRINTED CIRCUIT BOARD SERVICING

5-18 Excessive heat or pressure can lift the copper strip from the board. Avoid damage by using a low power soldering iron (50 watts maximum) and following these instructions. Copper that lifts off the board should be cemented in place with a quick-drying acetate base cement having good electrical insulating properties.

5-19 A break in the copper should be repaired by soldering a short length of tinned copper wire across the break.

5-20 Use only high quality rosin core solder when repairing etched circuit boards. NEVER USE PASTE FLUX. After soldering, clean off any excess flux and coat the repaired area with a high quality electrical varnish or lacquer.

5-21 When replacing components with multiple mounting pins such as transistor sockets and potentiometers, it will be necessary to lift each pin slightly, working around the components several times until it is free.

5-22 The procedure for the replacement of a component is as follows:

1. Apply heat sparingly to lead of component to be replaced on the conductor side of board. Remove component.
2. Reheat solder in vacant eyelets and quickly insert a small awl to clean inside of hole or drill out hole with a #60 drill (#50 for medium sized eyelet, #40 for large eyelet).
3. Bend clean trimmed leads on new part and carefully insert through eyelets in board.
4. Hold part against board and solder leads on conductor side of board.

5-23 POWER MESH RECTIFIER REPLACEMENT

5-24 In the event of a failure of one of the rectifiers (mounted on heat sinks in upper compartment) the following procedure should be followed for replacement:

1. Turn the unit off and remove the power cord from the power source.

2. Unscrew rectifier leads being careful to note where they were connected.
3. The rectifiers are threaded directly into the heat sink. Apply Penetrox A to the mating surface of the new rectifier but not to the threads.
4. Start the new rectifier in the threaded hole and tighten for the following maximum stud torque ratings: SCR C45, 150 inch - pounds. Rectifier 1N1184A, 30 inch - pounds.

5-25 TROUBLE SHOOTING

5-26 GENERAL

5-27 PRE-TURN ON CHECKS. Before energizing the unit, check the following items:

1. Presence of 230VAC (or 208/460) at the plug which connects to the receptacle on the rear of the unit. (Check three phases).
2. Straps on the programming terminal strip on the rear of the unit are placed properly and tightened.
3. Visually inspect for broken leads on the printed circuit board, controls on the front panel and the meters. Inspect the main bridge for loose connections. Inspect the printed circuit board for burned, charred or broken components.

NOTE: If component is found to be burned, charred, or broken on the printed circuit board, the cause of such a failure must then be located.

5-28 OPEN LOOP. In certain types of power supply failure (such as uncontrolled output conditions) it is desirable to open the feedback loop in order to be able to trouble shoot the unit without exceeding voltage limits on the output capacitors, etc. In the Model 6456A, removal of transistors Q16, Q17 and Q18 (blocking oscillator transistors) breaks the loop between the error amplifiers and the SCR's by disabling the blocking oscillators.

1. If an output still exists after this test, the trouble probably lies in the main power bridge rectifier.
2. If no output exists, the trouble lies in or prior to the blocking oscillator circuit and trouble shooting can proceed safely.

5-29 IN CIRCUIT OHMMETER MEASUREMENTS OF MAIN POWER BRIDGE RECTIFIERS. If a failure is suspected in the power rectifier bridge circuit, a resistance measurement will most often identify the faulty component. Breakdown of the reverse characteristic (or forward characteristic in the case of SCR's) may be determined by measuring the resistance from the anode on rectifier, cathode on SCR to their respective heat sink with the common side of the ohmmeter connected to the stud (heat sink).

5-30 Due to the characteristics of a bridge circuit, a resistance measurement test to find a faulty diode will not indicate which diode to be at fault. After finding a fault, it will be necessary to disconnect all the wires to the devices and make further measurements on the now disconnected diodes to determine which one is faulty.

5-31 When completely disconnected, SCR's should measure high resistance from cathode to anode and from gate to anode with either end connected to the common side of the ohmmeter. The resistance from gate to cathode should be approximately 200 ohms with either gate or cathode connected to the common side of the ohmmeter. The Power rectifiers should read high resistance with the cathode connected to the common side, and lower resistance when the anode is connected to the common side. It is important to note that the stud is the cathode of the fixed rectifiers but is the anode of the SCR's.

5-32 DC VOLTAGES

5-33 All measurements as made with a Simpson Model #269 VOM at medium input line voltage and zero output conditions except as indicated to be otherwise. Polarities indicated are for first test point ("FROM") with respect to second test point. All voltages are ±10% unless noted otherwise.

	FROM	TO	VOLTAGE	OUTPUT CONDITIONS
1.	20	-out (or -S)	-30VDC	See Note 1
2.	17	-out	-14 ±2VDC	
3.	18	-out	-6.2 ±0.4VDC	
4.	A10	-out	+6.2 ±0.4VDC	
5.	19	-out	+6.4 ±0.4VDC	
6.	47	-out	-28VDC	Relay Off (Low Line)
7.	47	-out	+5.5VDC	Relay On
8.	12	-out	+3 ±0.5VDC	See Note 2
9.	13	-out	+3 ±0.5VDC	See Note 3
10.	15	-out	Control Signal	See Note 4

Note 1: 360 cycle ripple.

Note 2: Voltage as indicated for constant voltage mode and supply producing output power. When voltage control off, T.P. 12 about +0.5VDC. When in constant current operation, T.P. 12 about +6VDC.

Note 3: Voltage as indicated for constant current mode and supply producing output power. When current control off, T.P. 13 about +0.5VDC.

Note 4: In constant voltage mode: Voltage control off T.P. 15 -13VDC; voltage just on T.P. 15 -10VDC; maximum load T.P. 15 +2VDC.

5-34 INSULATION AND CONTINUITY TESTS

5-35 Good insulation should exist between chassis ground and the output busses. In cases where the output busses display a low resistance to chassis ground, insure that the condition is not caused by extreme dirt buildup in the cooling compartment (bridge rectifiers).

5-36 Continuity measurements as outlined below will indicate the condition of the connecting wires between the printed circuit board, the SCR's and the output busses. Lack of continuity (in all instances, continuity means zero ohms resistance) can usually be traced to an open lead, most often where that lead is connected to an eyelet on a printed circuit board.

Continuity should exist between:

1. The positive output bus and the + terminal on the printed circuit board.
2. The negative output bus and the - terminal on the printed circuit board.
3. Test points 25, 30, 35, and the gate leads of the SCR's (that is, continuity between 25 on the board and one SCR gate lead). Test points 26, 31, 36, and the cathode leads of the SCR's.

5-37 SYMPTOMS AND CLUES

5-38 Poor Load Regulation:

1. Reference voltage -6.2VDC may be varying.
2. Insure that the current limit circuit is not starting to limit.
3. Insure the measurements of load regulation are done between +S and -S.
4. Check transistors Q1, Q2, Q8, Q10, and Q11.

5-39 Poor Line Regulation:

1. Check for presence and stability of -6.2VDC, -14VDC and +6.4VDC.
2. Insure that the current limit circuit is not starting to limit.
3. Check transistors Q1, Q2, Q8, Q10, and Q11.

5-40 Excessive Ripple Voltage:

1. Lack of firing of one or more SCR:

   a. Adjust R87 and R88 for presence of three phases and balance ripple.

2. Check the filter capacitors for a leaky or shorted unit. Failure will probably be indicated by a blown or protruding membrane on the exhaust valve near the terminals.

5-41 No Output or Uncontrolled Output:

1. Check meters.

2. Check presence of input power (all phases).

3. Check presence of -32VDC, -14VDC, -6.2VDC, +6.4VDC.

4. Check the strapping on the rear programming terminal strip, particularly the voltage programming terminals.

5. Check that relay K1 "clicks" ON as line voltage is brought up.

6. Check test points 12, 13, and 15 for voltage as described in 5-33 (8, 9, and 10).

7. Check the bridge diodes (static and SCR's) with an ohmmeter for a faulty device.

8. Check for presence of gate pulses at SCR's.

5-42 Insufficient Output (voltage and/or current):

1. Check meters.

2. If insufficient voltage, insure the current limit is not operating.

3. Refer to 5-41.

5-43 Current Limit Inoperative:

1. Check the straps on the programming terminal strip.

2. Check as per 5-33 (9).

3. Check transistor Q9.

5-44 Excessive Drift:

1. Check the stability of -6.2VDC.

2. Check the VOLTAGE control for excessive noise (R9).

3. Check for cold solder joints and/or noisy resistors (R1, R8, R2).

4. Check transistor Q1, Q2.

5-45 DETAILED CALIBRATION PROCEDURE

5-46 GENERAL

5-47 The following calibration procedure should be performed only after definite indications exist of trouble in the unit or after components have been changed in the circuitry where the adjustments are located. Indiscriminate adjustment of the internal controls to "refine" the settings may actually cause trouble.

5-48 The calibration procedures may be performed independently.

5-49 The differential or digital voltmeter serves two functions: that of a voltage standard (0.1%), and as a measuring device for measuring changes in voltage of millivolts. In the case where neither a digital nor differential voltmeter is available, substitute means can be derived to perform the same functions. Incremental voltages may be measured by connecting a DC source (another power supply or a battery, whose output voltage is approximately equal to the supply output voltage) in opposition to the output of the supply under test and measuring the difference between the two voltages. By adjusting the bucking voltage equal to the supply voltage (within 0.5VDC) the most sensitive scale of a multimeter can be used to detect changes as small as 20 mv in the supply voltage (assuming the bucking voltage stability is significantly better than 20 mv for the measuring period).

5-50 REQUIRED TEST EQUIPMENT

5-51 A list of the required test equipment is shown in Table 5-1, together with recommended manufacturers and model numbers. A test equipment wiring diagram is shown in Figure 5-3.

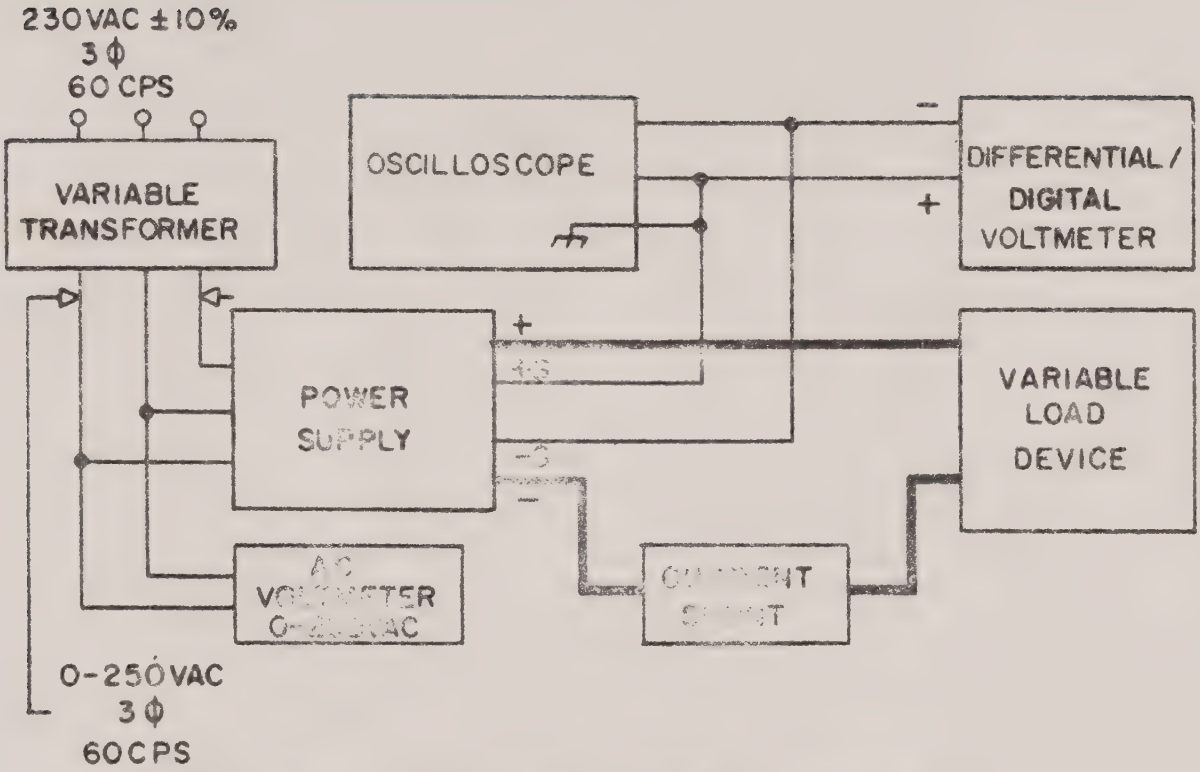


FIG.5-3 TEST EQUIPMENT WIRING DIAGRAM

ITEM	INSTRUMENT	RECOMMENDED TYPE	CHARACTERISTIC AND/OR USE
1	Variable Transformer	General Radio Variac No. W30HG2	6.5 KVA - open delta - 0-270 VAC
2	Ammeter Shunt	Weston 0041227	6450--50 mv, 500 amp shunt- 6453--50 mv, 200 amp shunt- 6456--50 mv, 100 amp shunt- 6459--50 mv, 50 amp shunt- connected in series between load and supply.
3	Voltmeter	Simpson No. 8800	0-250 VAC voltmeter
4	Differential or Digital Voltmeter	John Fluke Co., Inc. No. 801H Differential voltmeter	Connected between +S and -S
5	Oscilloscope	HP No. 130B/C	Connected to power supply line through 3:2 connector, vertical amplifier grounded to chassis ground.
6	Shorting Strap		Fabricated from copper bus strap or wire-connected as directed across output in series with meter shunt.

Table 5-1. Recommended Test Equipment.

5-52 PROCEDURES

5-53 CALIBRATION OF VOLTAGE PROGRAMMING AND VOLTMETER.

1. Connect differential /digital voltmeter to +S and -S terminals, rotate CURRENT control counterclockwise. Remove strap A2 to A3 on rear barrier strip to remove front panel pot from circuit. Connect a 6.2K 0.1% resistor between +S and A2 taking the place of the pot.

2. Energize power supply.

3. Rotate CURRENT control clockwise until supply is in constant voltage operation.

4. Set output voltage to 31VDC ±150mv (as read on differential/ digital voltmeter) by adjusting shunt R8 (across the pullout resistor R1).

5. Calibrate front panel voltmeter to voltage measured on differential/ digital voltmeter with R111.

6. Rotate CURRENT control counterclockwise, turn power supply off and disconnect differential/digital voltmeter. Remove 6.2K resistor and replace strap A2 to A3.

5-54 FIRING CIRCUIT BALANCE ADJUSTMENT (Balanced output ripple voltage).

1. Connect oscilloscope to +S and -S terminals, connect load device to output terminals, rotate VOLTAGE control counter-clockwise and CURRENT control clockwise.

2. Energize power supply.

3. Set output conditions to approximately 28VDC and 100ADC as read on front panel meters.

4. Set oscilloscope to 100mv/cm and 5 msec/cm with AC coupling to vertical amplifier.

5. Adjust R87 and R88 for minimum 60 cps modulation of output ripple.

6. Rotate VOLTAGE control counterclockwise, turn power supply off and disconnect test equipment.

5-55 CALIBRATION OF CURRENT PROGRAMMING AND AMMETER.*

1. Connect load devices, rotate VOLTAGE control ccw. Remove strap from A5 to A6 on rear barrier strip (taking current front panel pot out of circuit). Connect a 200 ohm ±0.1% resistor between A4 and A6.

2. Energize power supply.

3. Rotate VOLTAGE control cw until supply is in constant current operation.

4. Set output current to 100 ±0.5 amp by adjusting shunt R22 (across the pullout resistor R12).

5. Calibrate front panel ammeter to current output by adjusting R112.

6. Rotate voltage control ccw, turn supply OFF. Remove 200 ohm resistor from A4 to A6 and replace strap A5 to A6.

5-56 TRANSIENT RESPONSE ADJUSTMENT

1. Connect load devices, connect oscilloscope to +S and -S terminals, rotate VOLTAGE control counterclockwise and CURRENT control clockwise.

2. Set oscilloscope to 500 mv/cm A.C. and 50 msec/cm sweep speed.

3. Energize power supply.

4. Set output voltage to 32VDC and set load to switch from 32 volts 100 amp to 32 volts 50 amp.

5. Switch load and observe that output voltage returns to within 300 mv of nominal within 50 msec. If return is too slow or there is excessive ringing, adjust R10.

*NOTE: The factory sets the current programming as a protection feature for a current limit of 110 amp at full pot setting. If more accurate programming is required, follow the procedure described.

TABLE 6.

REPLACEABLE PARTS

6-1 INTRODUCTION

6-2 This section contains information for ordering replacement parts for the SCR-3 series DC power supplies.

6-3 Table 6-1 lists parts in alpha-numerical order of their circuit designators and provides the following information:

A. Circuit Reference Number
B. Total Quantity Used In the Instrument
C. Part Description (See list of abbreviations below)
D. Typical Manufacturers, Part Number, Type, and Stock Number

6-4 Miscellaneous parts not indexed in Table 6-1 are listed at the end of Table 6-2.

6-5 ORDERING INFORMATION

6-6 To order replacement parts, address order or inquiry either to your authorized Harrison Laboratories sales representative or to Customer Service, Harrison Laboratories, 100 Locust Avenue, Berkeley Heights, New Jersey.

6-7 Specify the following information for each part:

A. Model and complete serial number of instrument
B. Circuit reference designator
C. Description

6-8 To order a part not listed in Table 6-1 or 6-2, give a complete description of the part and include its function and location.

Reference Designators

C	= capacitor	K	= relay	RT	= thermistor
D	= diode	L	= inductor	S	= switch
DL	= delay line	M	= meter	T	= transformer
F	= fuse	P	= plug	V	= vacuum tube, neon bulb, photocell, etc.
FL	= filter	Q	= transistor		
		R	= resistor		

ABBREVIATIONS

coef = coefficient
com = common
comp = composition
conn = connection
dep = deposited
det = detector
EIA = Tubes and transistors selected for best performance will be supplied if ordered by H-Lab stock numbers; tubes or transistors meeting Electronic Industries' Association standards will normally result in instrument operating within specifications.
elect = electrolytic
encap = encapsulated
f = farads
fxd = fixed
Ge = germanium
grd = ground (ed)
h = henries
incd = incandescent
ins = insulation (ed)
K = kilohms
m = milli = 10^{-3}
M = megohms
ma = milliamperes
minat = miniature
mfr = manufacturer
mtg = mounting
my = mylar
NC = normally closed
Ne = neon
NO = normally open
NPO = negative positive zero-zero temperature coefficient
obd = order by description
p = peak
pf = picofarads = 10^{-12} farads
pp = peak-to-peak
pos = position (s)
pot = potentiometer
rect = rectifier
rot = rotary
rms = root-mean-square
rmo = rack mount only
s-b = slow blow
sect = section (s)
Si = silicon
sl = slide
td = time delay
tog = toggle
tol = tolerance
trim = trimmer
var = variable
w/ = with
W = watts
ww = wirewound
w/o = without
* = optimum value selected at factory, average value shown (part may be omitted).

MANUFACTURERS

AB	Allen-Bradley	Kulka	Kulka Electric
B	Bendix Corp	Mot	Motorola, Inc.
Beede	Beede Elec. Instr. Co. Inc.	RCA	Radio Corp of America
Buss	Bussman Mfg. Co.	Reliance Mica	Reliance Mica Corp.
Carling	Carling Electric Co.	Semcor	Semcor Corp.
CTS	CTS Corporation	Sloan	Sloan Company
Elco	Elco Corporation	Sprague	Sprague Electric
GE	General Electric Co.	Superior	Superior Electric
GI	General Instrument Co.	Sylv	Sylvania Electric
HH	Hardwick-Hindle, Inc.	TI	Texas Instruments
Hoff	Hoffman Electric Co.	WL	Ward Leonard Electric

REVISION:

Please note the following changes in the 6456A Parts List.

Add VR3 (1N968A) with zener diode 20.5 V ±5% 400 mw
#1902-0182 FSCM Cont. Device.

K1 (Circuit breaker) # should be: 6041H170A.

Change: R105, 3.9K 1 watt
R104, 8.2K 1/2 watt
C43, 5μf 65V

And Add: CR65 1N485B
--- to ---

ECN335

Phase Protection Circuit.

Delete R92.

ECN 502

Change: Q13 from 2N1377 to 1853-0001
R47 from 270 ohm to 100 ohm

Transistor Socket and PCB remain same.

ECN534
2/9/65

Circuit Reference Number	Description	Quantity	Mfg. Part # or type	Mfg.	Mfg. Code #	HP Stock #	A
CR10	Power Rect. Si	1	1N3261R	Westinghouse			3
CR11	Not Assigned	-	-	-	-		-
CR12, 13, 14	SCR	3	C45A	GE	03508		6
CR15, 16, 17	Power Rect. Si.	3	1N1184A	Delco	16758		6
CR18, 19, 20, 21, 22, 23, 62	Rect. Si 500MA 200PRV	7	1N3253	RCA	02735	1901-0026	14
CR63	Power Rect. Si	1	1N1563	Moto.	04713		3
DS1	Indicator Light Neon	1	858-R	Sloan	08717	1450-0048	2
K1	Relay Current DC 200 amp	1	6041H134A	H-Lab	09182		3
L1	Inductor Nom 1.2μh	1	645692	H-Lab	09182		2
Q1, 2, 4, 5, 21	SS NPN Si	5	4JX16B533	GE	03508		10
Q3, 7, 12, 15, 19	Not Assigned	-	-	-	-		-
Q6, 8, 9, 13, 16, 17, 18	SS PNP Ge	7	2N1377	TI	01295		14
Q10, 11, 14	SS NPN Si.	3	4JX11C710	GE	03508		6
Q20	Power PNP Ge	1	B1203	Bendix	83298		3
R1	fxd, WW 1.4K ±5% 3W 20ppm	1	242E1425	Sprague	56289		2
R2, 5, 54	fxd, comp 3.9K ±5% 1/2W	3	EB3925	AB	01121	0686-3925	-
R3, 4	fxd, comp 2.7K ±5% 1/2W	2	EB2725	AB	01121	0686-2725	-
R6	fxd, comp 130K ±5% 1/2W	1	EB1345	AB	01121	0686-1345	-
R7, 16	fxd, comp 5.6K ±5% 1/2W	2	EB5625	AB	01121	0686-5625	-
R8, 22, 109	fxd, comp Selective ±5% 1/2W	3		AB	01121		-
R9	Var. WW 10K	1	10031-10K	H-Lab	09182		2
R10, 24, 87, 88, 111	Var. WW 5K Modify	5	Type 110-P4	H-Lab	09182		10
R11, 15, 38, 41, 46, 53, 83, 84, 85, 86, 89, 90, 110	Not Assigned	-	-	-	-		-
R12	fxd, WW 4.3K ±5% 3W 20ppm	1	242E4325	Sprague	56289		2
R13, 26, 29	fxd, comp 470 ohms ±5% 1/2W	3	EB4715	AB	01121	0686-4715	-
R14	fxd, comp 27K ohms ±5% 1/2W	1	EB2735	AB	01121	0686-2735	-
R17	fxd, comp 390 ohms ±5% 1/2W	1	EB3915	AB	01121	0686-3915	-
R18, 43, 44, 45	fxd, comp 47K ±5% 1/2W	4	EB4735	AB	01121	0686-4735	-

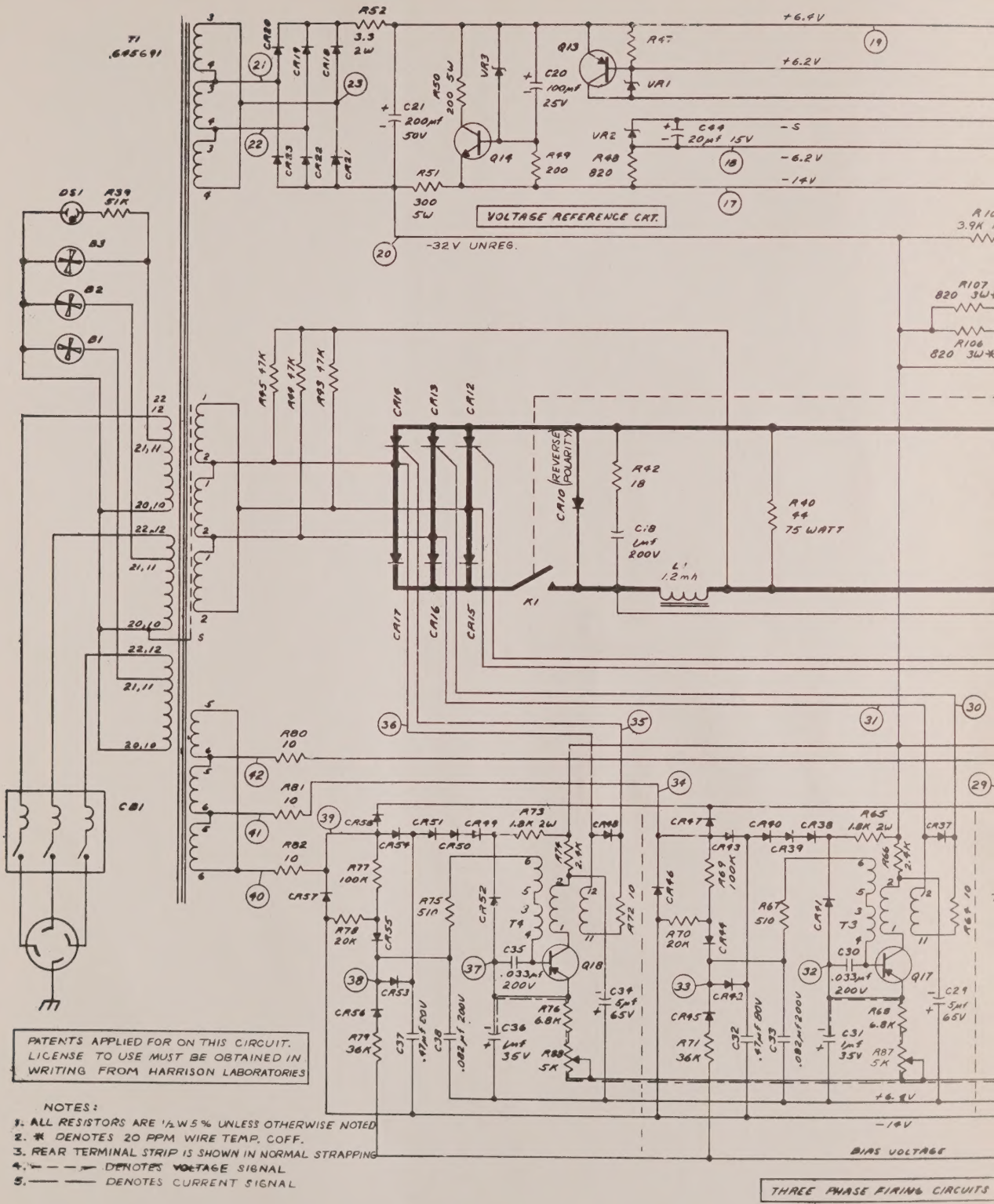
Circuit Reference Number	Description	Quantity	Mfg. Part # or type	Mfg.	Mfg. Code #	HP Stock #	A
R19	fxd, comp 240K ±5% 1/2W	1	EB2445	AB	01121	0686-2445	-
R20	fxd, comp 1.5K ±5% 1/2W	1	EB1525	AB	01121	0686-1525	-
R21	fxd, comp 2K ±5% 1/2W	1	EB2025	AB	01121	0686-2025	-
R23	Var. WW 250 ohms	1	10031-250	H-Lab	09182		2
R25,30,102	fxd, comp 62 ohms ±5% 1/2W	1	EB6205	AB	01121	0686-6205	-
R27,28,62,70,78	fxd, comp 20K ±5% 1/2W	5	EB2035	AB	01121	0686-2035	-
R31	fxd, comp 3K ±5% 1/2W	1	EB3025	AB	01121	0686-3025	-
R32,36	fxd, comp 10K ±5% 1/2W	2	EB1035	AB	01121	0686-1035	-
R33	fxd, comp 1K ±5% 1/2W	1	EB1025	AB	01121	0686-1025	-
R34,91,94	fxd, comp 100 ohms ±5% 1/2W	3	EB1015	AB	01121	0686-1015	-
R35,37,68,76	fxd, comp 6.8K ±5% 1/2W	4	EB6825	AB	01121	0686-6825	-
R39	fxd, comp 51K ±5% 1/2W	1	EB5135	AB	01121	0686-5135	-
R40	fxd, WW 44 ohms ±5% 75W	1	Type 6BR-37	HH	73978		2
R42	fxd, comp 18 ohms ±5% 1/2W	1	EB1805	AB	01121	0686-1805	-
R47	fxd, comp 27 ohms ±5% 1/2W	1	EB2705	AB	01121	0686-2705	-
R48	fxd, comp 820 ohms ±5% 1/2W	1	EB8215	AB	01121	0686-8215	-
R49,95	fxd, comp 200 ohms ±5% 1/2W	2	EB2015	AB	01121	0686-2015	-
R50	fxd, WW 200 ohms ±5% 5W	1	Type 5XM	WL	63743		2
R51	fxd, WW 300 ohms ±5% 5W	1	Type 5XM	WL	63743		2
R52	fxd, WW 3.3 ohms ±5% 2W	1	Type BWH	IRC	07716		2
R55,98	fxd, comp 12K ±5% 1/2W	2	EB1235	AB	01121	0686-1235	-
R56,64,72,80,81,82	fxd, comp 10 ohms ±5% 1/2W	6	EB1005	AB	01121	0686-1005	-
R57,65,73	fxd, comp 1.8K ±5% 2W	3		AB	01121		-
R58,66,74	fxd, comp 2.4K ±5% 1/2W	3	EB2425	AB	01121	0686-2425	-
R59,67,75	fxd, comp 510 ohms ±5% 1/2W	3	EB5115	AB	01121	0686-5115	-
R60	fxd, comp 9.1K ±5% 1/2W	1	EB9125	AB	01121	0686-9125	-
R61,69,77,103	fxd, comp 100K ±5% 1/2W	4	EB1045	AB	01121	0686-1045	-
R63,71,79,93	fxd, comp 36K ±5% 1/2W	4	EB3635	AB	01121	0686-3635	-
R92	fxd, comp 1 Meg. ±5% 1/2W	1	EB1055	AB	01121	0686-1055	-
R96	Sensing Resistor	1	645344-2	H-Lab	09182		2
R97	fxd, comp 3.3K ±5% 1/2W	1	EB3325	AB	01121	0686-3325	-
R99	fxd, comp 51 ohms ±5% 1/2W	1	EB5105	AB	01121	0686-5105	-
R100	fxd, comp 82 ohms ±5% 1/2W	1	EB8205	AB	01121	0686-8205	-

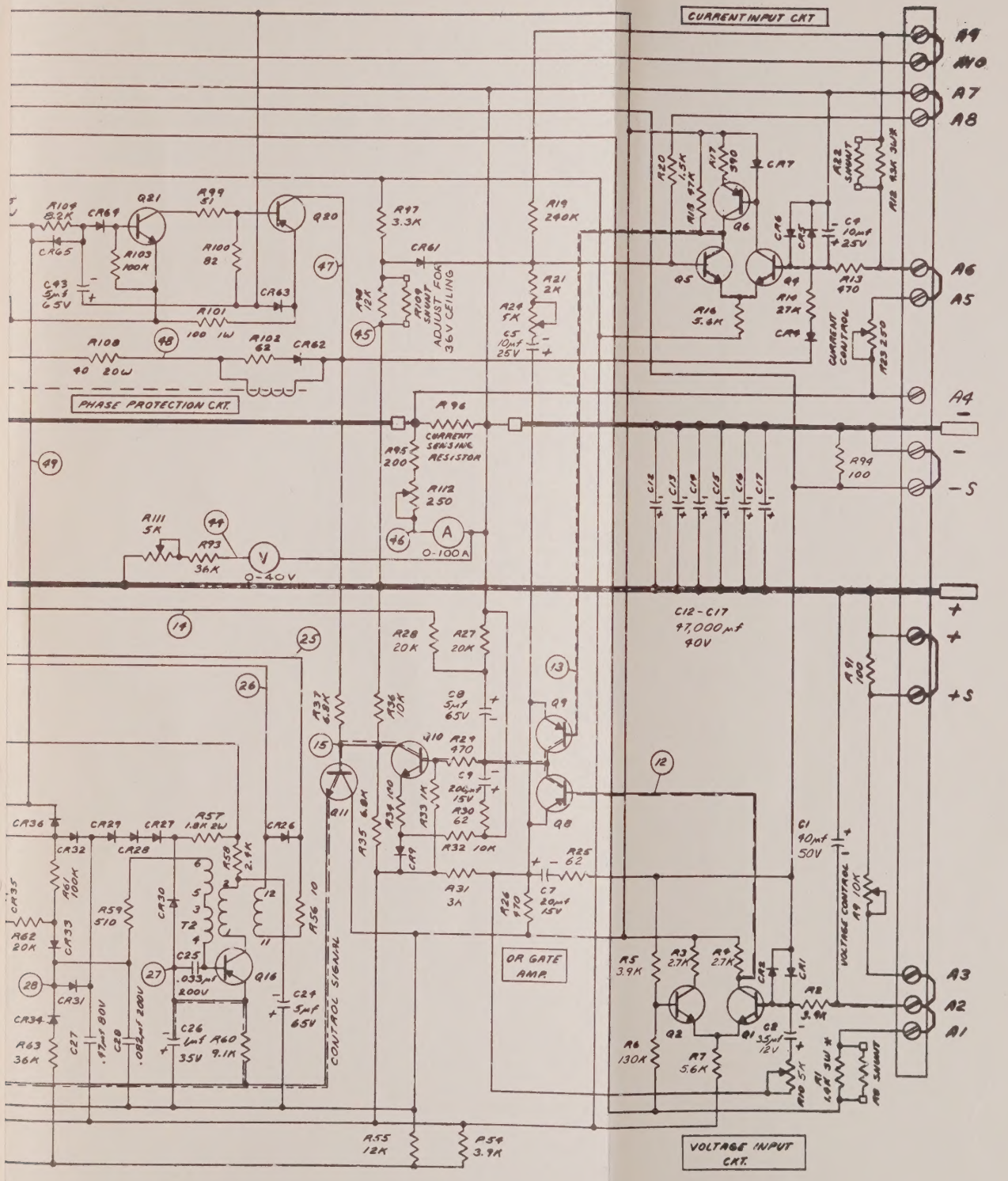
Circuit Reference Number	Description	Quantity	Mfg. Part # or type	Mfg.	Mfg. Code #	HP Stock #	A
R101	fxd, comp 100 ohms ±5% 1W	1	GB1015	AB	01121	0689-1015	-
R104	fxd, comp 5.1K ±5% 1/2W	1	EB5125	AB	01121	0686-5125	-
R105	fxd, comp 8.2K ±5% 1W	1	GB8225	AB	01121	0689-8225	-
R106,107	fxd, WW 820 ohms ±5% 3W 20ppm	2	242E8215	Sprague	56289		4
R108	fxd, WW 40 ohms 20W	1	2BRS53B	HH	73978		2
R112	Var. WW 250 ohms Modify	1	Type 110-F4	H-Lab	09182		-
T1	Power Transformer	1	645691	H-Lab	09182		2
T2, 3, 4	Pulse Transformer	3	H286A	H-Lab	09182		6
VR1, 2	Diode Zener 6.2V	2	1N821				4
VR3	Diode Zener 20V	1	1N968A				3
VR4	Strap	1					-
	Meter Face 0-40V	1	10085	H-Lab	09182		2
	Meter Face 0-100A	1	100172	H-Lab	09182		2
	Meter Movement Hoyt 4-1/2" movement 1 mill 100 ohms	2		H-Lab	09182		4
	Case Rear Half	2		H-Lab	09182	G182A-9	4
	Case Assembly Front	2		H-Lab	09182	G181A-5	4
	Disc Assembly (Part of Item 5)	2		H-Lab	09182	G181A-3	4
	Fill. Hd. Mach. Screw #3-48 x 1/4" lg. (part of Item 4)	8		H-Lab	09182	0525-0007	16
	Nut #6-32 3/32 Thk. 1/4 across flat	4		H-Lab	09182	2500-0001	8
	Rubber Foot	4	F7264A	Bud			8
	Transistor Heat Sink	1	3AL635-2R	Birtcher			2
	Transistor Socket	10	3305	Elco	91662		10
	Barrier Strip	1	600A-3	Kulka	75382		1
	Barrier Strip	1	599-Z-14	Kulka	75382		1
	Jumper	7	600-J	Kulka	75382		7
	Motor Fan HP Dwg. #50MS-1176	2	G5-CW-27255-6 GI			3140-0010	4
	Motor Fan	1	1075	Howard			2
	Casting Mach.	2	5243-L-346	H-Lab	09182		4

Circuit Reference Number	Description	Quantity	Mfg. Part # or type	Mfg.	Mfg. Code *	HP Stock #	A
	Blade Fan	2	50MS-3466	H-Lab	09182	3160-0034	4
	Blade Fan 4" blade, CCW rotation Hub pos. B, 1/4" bore	1		Torrington			2
	Shoulder Washer	38	100174-3	H-Lab	09182		-
	Knob 1" dia.	2		H-Lab	09182	G74G	4
	Connector 4 wire twist lock	1	7413G	Hubbell	74545		-
	Plug 4 wire twist lock	1	7408G	Hubbell	74545		-

A Recommended spares for one year for 10 units.

* As listed in Federal Supply Code for Manufacturers H4-1 (March 1963).


T1
.645691
R52
3.3
2W
CR20
CR19
CR18
CR23
CR22
CR21
R50
200 5W
VR3
Q13
C20
100µf
25V
R47
+6.4V
VR1
+6.2V
C21
200µf
50V
Q14
R49
200
VR2
C44
20µf 15V
-S
R48
820
-6.2V
-14V
R51
300
5W
VOLTAGE REFERENCE CKT.
-32V UNREG.
DS1
R39
51K
B3
B2
B1
CB1
R85 17K
R84 17K
R83 17K
CR14
CR13
CR12
CR10 (REVERSE POLARITY)
R42
18
C18
1µf
200V
L1
1.2mh
R40
44
75 WATT
K1
CR17
CR16
CR15
R80
10
R81
10
R82
10
CR58
CR54
CR51
CR49
A73
1.8K 2W
CR48
CR47
CR40
CR38
R65
1.8K 2W
CR37
CR50
CR39
R77
100K
R75
510
CR52
T4
R78
20K
CR55
C35
.033µf
200V
Q18
R76
6.8K
R88
5K
C36
1µf
35V
C34
5µf
65V
R72
10
CR46
R69
100K
R70
20K
CR44
CR45
R71
36K
C32
.01µf 600V
C33
.082µf 1200V
CR41
R67
510
T3
C30
.033µf
200V
Q17
R68
6.8K
R87
5K
C31
1µf
35V
C29
5µf
65V
R66
2.4K
R107
820 3W
R106
820 3W
CR56
CR53
R79
36K
C37
.01µf 600V
C38
.082µf 1200V
+6.4V
-14V
BIAS VOLTAGE
PATENTS APPLIED FOR ON THIS CIRCUIT.
LICENSE TO USE MUST BE OBTAINED IN
WRITING FROM HARRISON LABORATORIES
NOTES:
1. ALL RESISTORS ARE 1/2W 5% UNLESS OTHERWISE NOTED
2. * DENOTES 20 PPM WIRE TEMP. COFF.
3. REAR TERMINAL STRIP IS SHOWN IN NORMAL STRAPPING
4. - - - - DENOTES VOLTAGE SIGNAL
5. —— —— DENOTES CURRENT SIGNAL
THREE PHASE FIRING CIRCUITS



JOB NO 6956 A	TITLE 6956 SCHEMATIC
	0-32 V 0-100 A — FIG. 5-1
	HARRISON LABORATORIES DIV OF HEWLETT-PACKARD

Warranty

Harrison Laboratories, a division of Hewlett-Packard Company, warrants each instrument manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and to replacing any defective parts thereof; electron tubes, fuses, and batteries are specifically excluded from any warranty. This warranty is effective for one year after delivery to the original purchaser when the instrument is returned, transportation charges prepaid by the original purchaser, and when upon our examination it is disclosed to our satisfaction to be defective. Our warranty for this instrument is rendered void if the unit has been modified, unless such changes have been made in accordance with written instructions received from Harrison Laboratories. If the fault has been caused by misuse or abnormal conditions of operation, or results from use in combination with any other items, repairs will be billed at cost. In this case, an estimate will be submitted before the work is started.

IF ANY FAULT DEVELOPS,
THE FOLLOWING STEPS SHOULD BE TAKEN:

A. Notify us, giving full details of the difficulty, and include the model number and serial number of the equipment. On receipt of this information, we will give you service data or shipping instructions. Do not return unit for repair without first contacting factory or sales representative for instructions.

B. On receipt of shipping instructions, forward the instrument prepaid to the factory. If requested, an estimate of the charges will be made before the work begins, provided the instrument is not covered by the warranty.

C. If the original carton and packing are not available, the instrument should be packed in a strong exterior container and surrounded by two or three inches of excelsior or similar shock-absorbing material. We advise that all returned equipment should be declared at full value to the carrier.

Harrison Laboratories reserves the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

This warranty is expressly in lieu of all other obligations or liabilities on the part of Harrison Laboratories, and Harrison Laboratories neither assumes, nor authorizes any other person to assume for it, any liability in connection with the sales of Harrison Laboratories instruments.

MP MASTER
MA27201